THE

Institution of Production Engineers.

PROCEEDINGS

OF THE

SESSION 1921-22.

VOLUME I.

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THE

INSTITUTION OF PRODUCTION ENGINEERS.

SESSION 1921–1922.

President, MR. MAX R. LAWRENCE.

Members of Council.

MR. H. C. ARMITAGE, King's Heath, Birmingham.
MR. WALLACE ATTWOOD, London.
MR. A. BUTLER, Chiswick, W.
MR. DORMER, Enfield.
MR. W. L. FISHER, Richmond, Surrey.
MR. G. H. HALES, Guildford.
MR. C. F. HAMMOND, Coventry.
MR. G. HEY, London, S.W.
MR. H. E. HONER, London, S.E.
MR. W. P. MEESON, Dumfries.
MR. T. E. PATTINSON, Walthamstow, London, E.17.
MR. S. B. ROBSON, King's Norton, Birmingham.
MR. J. D. SCAIFE, Newark-on-Trent.
MR. R. WARING-BROWN, Coventry.

Hon. Sec.

MR. A. T. DAVEY, 6, St. James's Square, Holland Park, London, W.11.

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THE
INSTITUTION OF PRODUCTION ENGINEERS.

THE INAUGURAL MEETING.

At a meeting held at Cannon Street Hotel, London, on Saturday, February 26th, it was decided to form an Institution of Production Engineers, and a provisional committee was appointed.

There was a large attendance when Mr. H. E. Honer, who had convened the meeting, opened the proceedings, and suggested that Mr. Cecil F. Hammond, Works Manager, Messrs. the M-L Magneto Syndicate, Coventry, should be asked to take the chair, a proposal which was unanimously adopted.

Mr. Honer then briefly outlined the circumstances which had led to the calling of the meeting. He thanked the many people who had written to him supporting the proposal that there should be an Institution of Production Engineers and also those who had come long distances to attend the meeting.

The meeting was the outcome of recent correspondence in *Engineering Production*, but the question had been raised in an editorial which appeared in Messrs. Alfred Herbert's works magazine in April, 1916.

The matter, however, had been revived in *Engineering Production*, and the speaker thought that an Institution of Production Engineers was essential. To prove this, they had only to look at the many firms in which there was great waste of time, and apathy as to the methods adopted.

There might be some who would argue that the existing institutions filled the needs of the production engineer. Personally, he was of the opinion that this was not the case.

In putting forward the suggestion that an Institution should be formed, he wished to make it quite clear that there would be no intention of interfering in any way between employer and employee. Having read out a long list of names of important engineers supporting the proposal, Mr. Honer left the meeting in the hands of the Chairman.

Mr. Hammond, after thanking the meeting for electing him Chairman, said he thought the best course would be to leave it to the meeting to discuss the whole question.

Mr. R. Waring Brown (Coventry) said he thought the greatest

reason why an Institution of Production Engineers should be formed was to give the production engineer a proper status. If an Institution was formed it would aid in developing a future generation of production engineers of a much better type than existed at the present time. He hoped that the Institution of British Production Engineers would be formed right away.

Mr. J. D. Scaife, Works Manager, Ransome and Marles Bearing Co., supported the view that there was a great need for such an Institution as that proposed to study production methods and to give the production engineer a status as definite as that of any other engineer.

He was rather inclined to suggest that the Institution should be called an Institution of Manufacturing Engineers and not an Institution of Production Engineers. He had heard the production engineer spoken of as being two or three grades lower down than the works manager, and in many cases he was a man who was concerned only with the first costs and not the total costs.

That position should be changed and greater authority given to the production engineer, but a status such as that could only be attained through such an Institution as was proposed.

In suggesting that it should be called an Institution of Manufacturing Engineers, therefore, he had in mind the furthering of that object because the term "manufacturing" was a much wider one than "production."

Mr. H. C. Armitage (Austin Motor Co.), in supporting the formation of the Institution, said that the title did not matter very much at the moment. The aim should be to get the best men to join, and then the Institution, whatever its name, would exert a very strong influence upon industry. Most of the existing institutions engaged in more or less scientific discussions which did not appeal to the practical man, and such discussions did not help the object that production men had in view. There would have to be a wise discrimination in fixing the classification of membership of the proposed Institution.

As to the objects of the Institution, it should be seen that it did not concern itself with the pushing of scientific management, as it was familiarly known, but they did want their workshop methods run on scientific lines and in a scientific manner, and that should be one of the principal props of their platform.

Another matter which should be one of the objects of the Institution was that of applying the lessons of unlimited production to normal conditions. It was essential, when they had a comparatively small job, to balance the plant to produce, say, from 100 to 250 articles forming one piece of machinery. It was quite a scientific job to produce such a machine having that number of pieces, because they would have some machines idle and some entirely single operation machines, and so on.

Mr. Atkinson (Redhill) said he had been a member of the

Institution of Mechanical Engineers for twenty-three years and fully agreed with the need for a new institution to cover production. Having regard to the wide field covered, he suggested that it might be called the Institution of Production Engineers and Managers. It might be objected that that was too long a title, but if they limited the title to the word "Production" then they would restrict their membership.

Among the matters which would have to be considered in forming the Institution was the holding of meetings in the provinces, because everybody could not come to London for meetings; the social side would also have to be looked after, and, if possible, some sort of club-room provided where members could meet. An official magazine was also essential, but here they were fortunate because there were one or two magazines dealing with production, and no doubt it would be possible to arrange with one of these to act as the official organ of the new Institution.

MR. HONER said it was open for those who joined the Institution to make its objects just what they desired. What he had in mind was that there should be more than one class of member, and that manufacturers themselves should be invited to join in some other class than that of full membership, which would apply to the actual production engineers. He also thought it would be possible to have an information bureau and to found centres in various parts of the country.

MR. BUTLER (Engineering Manager, Messrs. C. A. Vandervell & Co., Ltd.) said he sincerely hoped the Institution would be formed, and he hoped they would confine their discussions to working problems.

If they ran on highly technical lines, they would crowd out the lower grade man, who frequently had a fund of practical information.

They should encourage foremen to join and not confine membership to managers and similar people. He did not think the title of the Institution mattered very much, because they would attract people more by the objects than the title. The best thing they could do was to appoint a committee to draw up the constitution, and then call another meeting to discuss it.

A speaker supported the suggestion that membership should not be confined to the management or the theoretical or highly technical men. One of the most important parts in production was the design of highly efficient jigs and tools, and many of the most practical men in this direction might be barred from joining the Institution if the range of membership was kept too narrow.

MR. MARSTON said there was no denying the fact that the status of the production engineer to-day was something of an enigma. Speaking personally, as a production engineer, he had found his duties range from selling slag to dealing with the higher costs and not first costs.

Many other speakers expressed the hope that the Institution would be formed, and supported the necessity for keeping the highly technical side out of their discussions. Stress was laid upon the advantage likely to be gained by bringing in some of the foremen and others lower down, who for the most part had many practical ideas, the discussion of which would not only be to the benefit of production engineers generally, but would also be to the advantage of the firms in which these men are employed.

MR. H. GLASER said that after so many speeches in favour of the formation of the Institution, he felt a little trepidation in speaking from the opposite point of view. Everybody so far had spoken as if the Institution was in fact in being. He was keenly interested in all matters pertaining to production, but he could not help feeling that this would add yet another institution to the large number already existing, and augment the subscriptions which they all had to pay. There was the Institution of Junior Engineers and the Society of Engineers. There was also the Institute of Cost and Works Accountants and an Institute of Industrial Administration.

There was a Wireless Section of the Institution of Electrical Engineers, and he heard that it worked admirably.

Why should not they, in the present instance, ask the President and Council of the Institution of Mechanical Engineers to form a separate branch for production or manufacturing engineers? He could not see any vital objection to that course being adopted. Finance was a further important point to be considered, and that had hardly been mentioned. To make such an Institution a success and a really live body, there must be frequent meetings both in London and the provinces, and that demanded considerable funds.

If they formed a separate body, there would be overlapping expenses, which were already being incurred by other institutions. They would also need a library and reading rooms and other similar facilities which were already offered by existing institutions, and the expense of all these they would be relieved of if they joined up with some existing body, say as a separate section of the Institution of Mechanical Engineers. He agreed that in many cases at the present time the production engineer had not got the status in the works that he ought to have, but he did not know that the formation of a separate body, as compared with amalgamation in the form he had suggested, would bring about an improvement in status for a very long time.

On the other hand, amalgamation with some such body as the Institution of Mechanical Engineers would immediately confer a status upon them. There was no question that the value of the production engineer had been shown during the war, and his position was considerably better since the Armistice than it was before the war; moreover, he thought it would be very consider-

ably improved by amalgamation on the lines he had suggested with some other body.

It had been said that the Institution of Mechanical Engineers had never had a paper on production. He was not prepared to doubt that, but if it was the fact, it could be altered by ordinary constitutional representation to the Council of the Institution. Again, the advantages of having papers read in the provinces had been mentioned, and here again amalgamation with the Institution of Mechanical Engineers would at once provide the necessary facilities. He wished it to be understood that he was not there as an emissary of the Institution of Mechanical Engineers, but was expressing his own personal views.

As to the social side, which had been mentioned, there was already an Engineers' Club in Manchester, one was proposed for London, he believed one was being formed in Birmingham, and there was a proposal for one in Bristol and another in Glasgow. He agreed that some of the other Institutions were very starchy in their methods, such, for instance, as the Institution of Civil Engineers, whilst others were less formal, like the Institution of Automobile Engineers; but by forming a separate section of some other body and having less formal discussions among themselves, that objection would not hold. He therefore suggested that they should apply to, say, the Institution of Mechanical Engineers, and endeavour to form a separate section for production engineers.

MR. BUTLER said he could endorse some of the things the last speaker had said, especially as to the difficulties of finance. He himself had suggested affiliation with some other body, in a letter to *Engineering Production* a few months ago, but he had been away and was not aware what course events had taken since.

If they could possibly persuade the Institution to adopt them as a live and very energetic section, then they would have done something to give production engineers a status to start with. The R.A.C. had done a similar thing in forming the Junior Car Club, members of which had the use of certain parts of the premises at any time. Therefore he would rather like to see something done on these lines, even if it were only to send a letter to the President of the Institution of Mechanical Engineers asking his opinion on the matter.

MR. HONER said they would find that a great difficulty existed in regard to affiliation with some other body, inasmuch as in the majority of cases it was required that a man should pass a preliminary examination before he could become a member.

MR. GLASER: Only for certain grades.

MR. HONER agreed, but added that there were a large number of men in the country who could not get through any examination on paper, but who were yet the most practical men imaginable, and it was those men that the new Institution would cater for.

Had the Institution of Mechanical Engineers or any other body

thought that production would have become one of the most important features, they should at least have formed a section to deal with it. That was the thing that had to be considered.

He felt very strongly that an Institution of Production Engineers was essential to the trade of the country, and would do far more industrially in a very short time than the present institutions had done in all the years they had existed. If the existing institutions had fulfilled their true function in bringing home to manufacturers the importance of studying production methods, we should not have seen some of the things which were to be seen in the shops to-day. This country had stood pre-eminent in every respect in engineering throughout the world, and it was up to the production engineers to see that that position was maintained. He suggested that a resolution should be put to the meeting in favour of forming an Institution of Production Engineers.

Mr. Whittaker (London) referred to the proposed Bill of the Institution of Civil Engineers last year which sought to define an engineer. That was opposed by the Institution of Mechanical Engineers and others, but he regarded it as an attempt to restrict the activities of the engineer. For that reason alone he felt that affiliation with an existing institution would be unwise as a matter of practical politics.

The proposal to form a separate institution was then put to the meeting and carried with but three dissentients.

The following committee was appointed to draft rules, etc., and to report progress at a General Meeting to be held at 20, Tudor Street, London, E.C.4, on Saturday, April 2nd. Messrs. H. E. Honer, W. L. Fisher, A. Butler, J. W. Whittaker, Hammond, Scaife, Waring-Brown, Armitage and Atkinson, with Mr. A. T. Davey as hon. secretary.

Votes of thanks to the Chairman, Mr. Honer, and to Messrs Iliffe of *Engineering Production*, for the assistance and publicity they had accorded the meeting, closed the proceedings.

THE
INSTITUTION OF PRODUCTION ENGINEERS.

THE FIRST GENERAL MEETING.

A SECOND meeting in connection with the formation of the Institution of Production Engineers was held at 2 and 4, Tudor Street, London, on Saturday, April 2. There was again a large attendance, over which Mr. Cecil F. Hammond, of Coventry, presided.

THE CHAIRMAN, in opening the meeting, said:—For the sake of the members of this meeting who were not with us on February 26th, allow me to draw your attention to the way in which the Provisional Committee came into being and the task with which that Committee was entrusted. The Provisional Committee came into being as the result of your choice on February 26th, on which occasion they were freely elected from your number, with a mandate from yourselves to draw up a suggested constitution with by-laws under which you could elect to constitute yourselves a society or institution for the furtherance of the objects and aims there laid down. It was found to be necessary to form ourselves, under a Memorandum of Association, into an incorporated institution. This has been done, and under the proposed Articles it will be seen that the Council have power to co-opt further members up to 26, including President and Vice-Presidents, and therefore it will be understood that the Institution of Production Engineers is now duly formed. It is my intention shortly to ask your honorary secretary to read the Memorandum of Association to you so that you may judge of the results of the Committee's stewardship, after which the whole matter will be thrown open for your discussion and criticism.

May I also draw your attention to certain factors which have influenced the Committee in arriving at the constitution and by-laws? In the first place, it was decided that they should not ignore any ground which could be found to have been already covered by the work of existing institutions of a similar nature. In regard to this, the constitution may appear, on first sight, to be too ambitious in its comprehensive nature, but it requires to be pointed out that there are certain legal requirements to be met in the formation of any association or institution of this nature.

These requirements have naturally been fulfilled by other associations, and where these are directly applicable to our own constitution the Committee have had no hesitation in adopting the phraseology as it stands. I think all will agree with this procedure, as it is only following out the doctrine of the production engineer who teaches the repetition of the best recorded means, failing a better being available. I should like to draw your special attention to certain of the recommended by-laws. You will notice that the Committee have given special attention to the views expressed at the inaugural meeting, and in the by-law relating to qualifications, stress has been laid on the need to readily admit the eminently practical man and avoid the tendency shown by most existing institutions to become too academic and pedagogic. At the same time, it must be remembered that one of the aims and objects of the institution is to raise the status of the production engineer. The aim, then, has been to have a system of grading broad enough to allow of these two factors, and to this end you will find that one of the provisions in the rule on qualification is to the effect that the Council have the power, where necessary, to ask for a personal interview where the applicant can satisfy the Council of his claims to membership, without the need of a written examination. This, I believe, is a provision which you will not find in any other existing society, and it is believed that your judicious choice of a Council at the end of the inaugural year will be all that is needed to ensure that these points will be met. I will now ask the honorary secretary to read the Memorandum of Association which has been prepared.

THE HON. SECRETARY having read the Memorandum of Association. THE CHAIRMAN explained that it was necessary to have a Memorandum of Association before they could constitute themselves into an institution. They could not get the Registrar-General to look at them until such a memorandum had been drawn up, and the memorandum stated definitely that they were not a money-making concern. Otherwise they would have had to call themselves the Institution of Production Engineers, Limited, and it was only by putting themselves forward in such a Memorandum of Association as had been read that they were able to delete the word "Limited" from the end of the title. That was a necessary legal procedure, and he now asked for suggestions or modifications of the Articles of Association, which were in the hands of all present. The Articles of Association and By-laws, however, were different from the Memorandum of Association which had been read by the hon. secretary, and in discussing them perhaps it would be well to concentrate upon the clauses relating to the qualifications of membership. With regard to the Council, the present Provisional Committee had power to co-opt to the extent of a total of 26 members, and it was the intention to co-opt additional members in order to make the representation on the

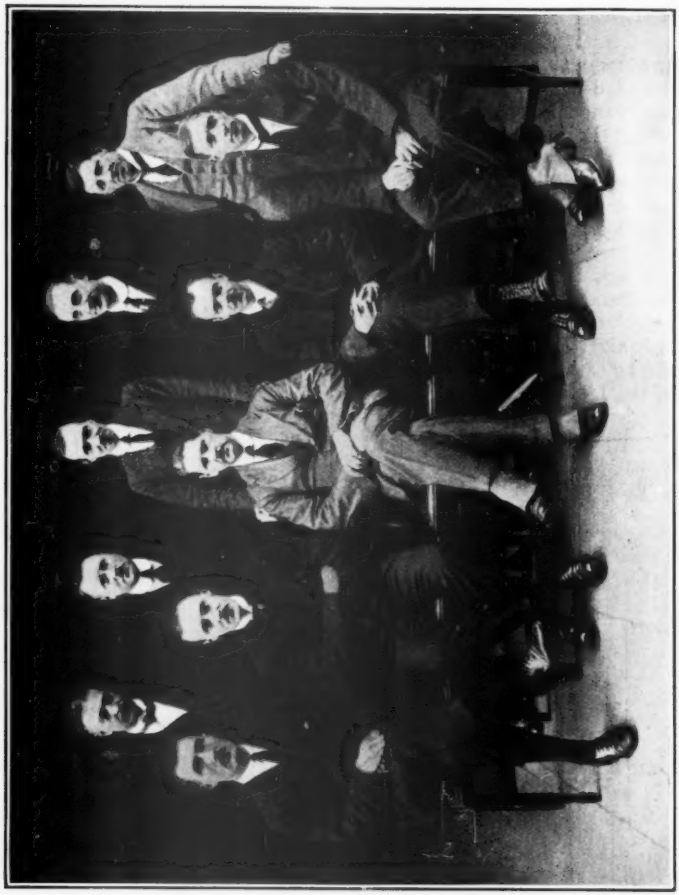
Committee cover as large an area of the country as possible. It was the ultimate aim to have proportional representation on the Council from all over the country, but that was not possible at the moment because local sections had not been formed.

MR. MAX LAWRENCE asked if the Memorandum of Association which had been read was *un fait accompli* or was it still subject to amendment.

THE CHAIRMAN said the position was that the Provisional Committee had decided to put themselves forward, as signatories to the Memorandum of Association, for incorporation, but it would take some time for that to go through. The formation of the Institution was actually in process in the form stated in the Memorandum of Association, and therefore was not subject to modification.

MR. MAX LAWRENCE thought it was going rather far, because it was a very important matter in starting an institution like this, to get things in proper form at the start, as it was very difficult to alter them afterwards. The Institution of Automobile Engineers had just been through that very process, and the Institution of Mechanical Engineers had also been through it. An alteration might take eighteen months or two years to get through. In the case of the Institution of Mechanical Engineers it took about three years and cost a great deal of money. There were certain things in the Articles of Association which his experience in other institutions suggested should be modified. The first was with regard to the use of letters denoting membership. One institution had had to go into this question recently in order to prevent these letters being used on unsuitable occasions or in unsuitable places, and it had been necessary to limit the size of the letters and the places where they could be used, and the circumstances in which they could be used. Paragraph 49 of the Articles was a new departure for any institution to allow graduates to use letters after their names. It was questionable whether associates or honorary members should be allowed to use them. Honorary members, he should say, ought not to. With regard to officers, he did not think it was necessary to employ a treasurer, especially as it was laid down that he should be a banker, because it would be an expensive business. Then it was stated that the secretary should give his whole time to the duties of his office. That, again, would involve a great expense which could be avoided if the secretary were allowed to do other work, as was done in the case of the Institution of Automobile Engineers. In that way they would be able to get a much better type of man than if they employed one on full time at what must be a small salary. Another point was that according to the Articles as drafted, firms could become honorary members. The Institution of Automobile Engineers had just inaugurated a class of Affiliates for firms, who could nominate one or more of their staff to be a member of the Institution.

although such members could not vote. These nominees could be changed from time to time, but they had the right to attend all the meetings, and the firm paid a subscription for each



J. D. Scaife (Newark-on-Trent). W. L. Fisher (London). J. W. Whitaker (London) A. T. Davey Hon. Sec. H. C. Armitage (Birmingham). C. F. Hammond Chairman (Coventry). A. Butler (London). H. E. Hoser (London). H. Atkinson (Redhill). R. Waring-Brown (Coventry).

The Provisional Council of the Institution of Production Engineers.

nominee. That matter had been very well worked out by the Institution of Automobile Engineers, and was worth consideration by the Institution of Production Engineers, because it was proving

a great benefit to the Institution of Automobile Engineers from the financial point of view and was likely to add to its prestige. Another departure from the usual practice was that under Rule 64, the election of the president was to take place at the annual general meeting. Whilst the experience of a ballot in the ordinary way was that very often not more than 10 per cent. of the members took the trouble to return their ballot papers, yet he did not think that was so mischievous as leaving it to the general body of members at the annual meeting. That was not at all a suitable method. Under Rule 85, dealing with the formation of local branches, there was likely to be a lot of trouble if the local branches were allowed to make anything which could be called rules. It was necessary to keep the control in the hands of the Council, and it was, in his opinion, essential that the chairman of the branches should attend the Council meetings and put in a minimum number of attendances. Only in that way could the branches be kept alive and in touch with headquarters. Otherwise, it would be found that the branches would draft rules which the Council could not possibly pass, and there would be a lot of trouble.

THE CHAIRMAN said that nothing mentioned by Mr. Max Lawrence was irrelevant, but he had been confusing the Articles of Association with the Memorandum. The Articles of Association which were in the hands of those present were quite temporary, and were before the meeting for the purpose of discussion and modification if thought fit. The Memorandum of Association which had been read out by the secretary was a separate thing; it was in the broadest possible terms, and it was necessary that it should be drawn up and presented to the Registrar-General before an application for incorporation could be made. The Articles of Association and By-laws, on the other hand, had yet to be finally drafted, and it was in order to facilitate the final drafting that suggestions were now asked for, and those made by Mr. Lawrence would be most valuable in assisting in the final preparation of the Articles of Association.

MR. MAX LAWRENCE said he had understood that the position was the other way round.

MR. H. E. HONER then moved:—

"That the Memorandum of Association be accepted."

MR. MAX LAWRENCE said he would have much pleasure in seconding that, but he wished to be quite clear about the formation of a Benevolent Fund. According to the Memorandum of Association as read by the Secretary, it seemed to him that members of the Institution would be precluded from benefit and that employees of the Institution and outsiders only would be allowed to benefit.

On reference to the Memorandum it was found that the wording bore this interpretation, but it was explained that that was not

the intention, and that members of the Institution would be included.

The resolution was put to the meeting and carried unanimously.

MR. HONER next moved :—

"That we here assembled, having regard to the proposed Articles of Association and By-laws, do hereby present ourselves for membership of the Institution of Production Engineers."

MR. A. BUTLER seconded.

The resolution was carried unanimously.

Discussion of Articles of Association.

The meeting then discussed the proposed Articles of Association and By-laws as drafted in the rough by the Provisional Committee.

THE CHAIRMAN explained that suggestions and recommendations would be noted and considered by the Provisional Committee, and the revised articles, modified in the light of the discussion, would be placed before another general meeting for final adoption.

MR. HONER moved that Articles 1, 2 and 3, as follows, be adopted :—

1. The name of the Association shall be "The Institution of Production Engineers."

2. The Registered Office of the Institution shall be situate in London, England.

3. The objects for which the Institution are established are :—

(*a*) To establish the status and designation of a production or manufacturing engineer.

(*b*) To promote the science of practical production in any branch of industry, and to give impulse to methods of production likely to be an asset to members of the Institution and the community.

(*c*) To enable engineers, manufacturers and specialists who are engaged in productive effort of any kind to meet, discuss, correspond, and generally to facilitate the interchange of ideas appertaining to the science and practice of manufacture.

MR. MAX LAWRENCE moved an amendment to add the words "or have been" before the word "engaged" in paragraph (*c*) of Rule 3. His object, he said, was to include those people who had been engaged in production in the past, although they might not be at the moment. The rule as it stood might keep out some very valuable members.

MR. HONER said he would, if Mr. Lawrence agreed, include the suggested addition in the original resolution.

MR. LAWRENCE agreed.

THE CHAIRMAN said he did not propose to put this forward as

a resolution, because the object of the discussion was to obtain suggestions for the Provisional Committee to work upon in finally revising the Articles of Association.

MR. FUNCK (Coventry) suggested that the designer should have more consideration than he appeared to have at present in the Articles, because he was as essential to production as the production engineer. Indeed, he very often worked up to the position of production engineer.

A MEMBER thought this point was covered by the three alternative conditions of membership for Associate members, in Rule 42, viz. :—

(*a*) Has received a good general education, or
(*b*) Has been regularly trained as a production engineer, and
(*c*) Has had subsequent employment for at least one year in a responsible position in the direction or supervision of industrial production.

THE CHAIRMAN said it was not suggested that there should be three alternatives, but only either of the first two, with the third, not necessarily (*a*) and (*b*) as well as (*c*). He agreed with Mr. Funck that the designer should be definitely mentioned, and it had been suggested that Rule 44, dealing with Associates, should read :—

" Shall be individuals who, not being production engineers, have been connected with design, tool design, research, experiment, or organisation for production. . . ." The rest of the rule would remain. That, he thought, would meet the suggestion.

MR. JARDINE called attention to the latter part of Rule 44, which said that an honorary member could nominate an associate. Did that mean that an honorary member would nominate anybody, whether he was desirable or not?

THE CHAIRMAN replied that " honorary member " there meant a firm, which must nominate someone to look after its interests. It might be advantageous to add the words " to look after his interests."

MR. MAX LAWRENCE said this difficulty might not arise if the suggestion he had made as to a class of affiliates were adopted. They would then have an honorary member in the ordinary sense—a man whom it was an honour to the Institution to have as an honorary member, who might or might not give a contribution to the funds. He should certainly strongly oppose an associate being the nominee of an honorary member in the ordinary sense, and being allowed to use initials after his name. They might get anybody in.

THE CHAIRMAN thought the case might be met if the words " who would be otherwise qualified for membership " were added.

MR. LAWRENCE thought not, as under Rule 49 any associate could use the letters A.I.P.E. after his name, and they might, by

such nominations, get associates in the election of whom the Council would have no say.

THE CHAIRMAN said he was glad to have that pointed out.

MR. LAWRENCE thought the whole difficulty would be short-circuited if they had honorary members in the ordinary way and a class of affiliates as representatives of firms.

With regard to Rule 41, clause (*c*), which dealt with qualifications for full membership, it read "Has for a sufficient period held an important position of independent responsibility in connection with the direction of industrial production." As an engineering institution, how far was that intended to include allied industries which were, so to speak, on the borderline of engineering? It would be adivsable at this stage, he thought, to leave the objects as wide as possible because there might arise new industries which it would be desirable to include in the scope of the Institution.

MR. ATKINSON said the Provisional Committee had had this point in mind when drafting the Articles, and it would be noticed that, except in the title, the word "engineer" had been left out, with the object of making the scope of the Institution as wide as possible. Only last week in Glasgow he was speaking to a man interested in the production of confectionery who was not an engineer, but he had expressed a wish to become a member of the Institution in order to learn what he could about production methods generally.

MR. MERCER said that at the previous meeting one of the main planks in the platform of the new Institution was that it should be a body of production engineers, and although there were many other forms of production which were as important from the national point of view as engineering, yet he thought it essential that the word "engineer" or "engineering" should be retained in the Articles. He therefore suggested that in paragraph (*c*) of Rule 41, already referred to, the word "industrial" should be replaced by the word "engineering."

MR. ATKINSON thought that all types of production experts would be roped in with the wording as it stood.

MR. MAX LAWRENCE thought the phraseology of Rule 41 might be improved in order to effect this.

THE CHAIRMAN said he did not think the word "industrial" would keep engineers from joining, because in all industrial processes there must be engineers concerned with production in some form.

MR. MAX LAWRENCE said if it were the intention to get in engineers connected with any type of production, then it would be better to leave out the word "engineer," because a great many firms did not employ production engineers as such; they were called by all sorts of names, and yet they would be eligible for membership.

MR. ATKINSON said the gentleman he had referred to was not an engineer at all, but was a staff organiser, and he wished to join the Institution because he was closely engaged in producing confectionery in the best possible manner. He himself foresaw the time when the whole of industry throughout the country would be looking to the Institution for information on production methods of all kinds, and it was for that reason it had been thought well not to make the word "engineering" too prominent.

MR. ATWOOD said the whole question turned upon whether the production engineer was the man who engineered production—that was what he took it to mean himself—or did they mean by production engineer the man who was engaged in getting efficient production from plants whose function it was merely to produce products which could be designated as engineering? If the latter, more limited, definition were adopted, then they would be depriving themselves of the value of the experience and research work of many people which they could otherwise avail themselves of.

MR. FUNCK thought the Institution should embrace all engaged in the science of production, no matter what the business was.

MR. HONER said he thought the position was made quite clear in Rule 41, paragraph 2, which stated "Has attained a position such as, in the opinion of the Council, qualifies him for the distinction of membership." He believed that would cover everything raised by the previous speakers.

MR. MAX LAWRENCE remarked that the pertinent thing was Rule 3 (*a*), which had been passed, viz., "To establish the status and designation of a production or manufacturing engineer." That, to his mind, ruled out the confectioner.

MR. HONER pointed out that Rule 3 (*c*) provided for those engaged in productive effort of any kind to meet and discuss. That covered the whole field.

MR. LAWRENCE said that could be done without certain people being members of the Institution.

MR. ATKINSON referred to Rule 46, which reads "Candidates will be required to produce evidence in writing for consideration by the Council, and may be required to attend personally a meeting of the Council for further examination." Under this rule any candidate for election would have to prove himself worthy of election.

MR. ROBSON suggested the possibility of a large number of confectioners, or similar people, getting into the Institution and being strong enough to form a Council. In that event the engineering character of the Institution might disappear.

MR. J. W. BUCHANAN said the Institution must be made as virile and interesting as possible and must not start off with a flash in the pan and then all interest dwindle away. If many people who were outside engineering came in, those who were engineers would lose interest.

THE CHAIRMAN said the idea was that such people as had been referred to would come into certain grades and they would not have the power of voting.

MR. WARING-BROWN said that although as the rules stood a man interested in the engineering side of sausage making or bread baking would be eligible, it was still left to the discretion of the Council whether he should be elected or not.

MR. SCAIFE thought there need be no fear that they would be swamped by people who were not engineers. The point had received very careful consideration by the Provisional Committee, and it was felt that the scope should be as wide as possible. People who studied the costs of manufacture of any article were as much production engineers as a production engineer in the narrow sense, and they could help each other considerably by studying each other's methods. It would certainly need a very clever lot of men who were not actual engineers to get into the Institution and swamp the Council, and he had no fear of that kind himself.

MR. MAX LAWRENCE said there were obviously two sets of opinions on the matter, and in order to bring the point to an issue he would suggest that in section (*c*) of Rule 41 the words "industrial production" should be replaced by "engineering production." That would enable the engineer engaged in the confectionery trade, for example, to be eligible.

THE CHAIRMAN, in order to ascertain the feeling of the meeting, asked whether it was agreed that Rule 41 as it was printed in the rough draft should stand.

No hands were raised in favour of this.

THE CHAIRMAN then asked for suggested modifications of Rule 41, dealing with the qualifications for full membership.

MR. HALES suggested that the qualifications should be restricted entirely to engineers; then it would not matter whether they were baking engineers, mining engineers, or any other class, because the term "engineer" covered a very wide scope.

MR. E. D. BALL seconded. He said it did not matter whether a man, who was an engineer, was associated with any particular industry, because there must be engineers connected with all trades.

MR. MAX LAWRENCE said he presumed is was meant that an engineer was a man who had served his time in an engineering works.

THE CHAIRMAN: Certainly.

The proposal was put to the meeting and carried unanimously.

THE CHAIRMAN said that although that gave the general impression of the meeting, it would still be well to discuss the matter with a view to getting further ideas on the subject.

MR. H. H. FANTHORPE thought the position would be cleared if (*c*) in Rule 41 were made to read "in the engineering trades" at the end, after the words "industrial production." It was not

his intention to become a member of the Institution if he had to listen to papers dealing with sausage making, bread baking, etc., although they might be very interesting. His idea of the Institution was that it should consist of men engaged in practical engineering.

MR. HONER said that as the one who was responsible for the idea of the Institution being formed, it was his intention to have in it only those who could be called craftsmen. They should stick to that very strongly. They wanted the best engineering brains of the country in the Institution, and if the words "in the engineering trades" were added at the end of 41 (*c*), he thought they would achieve that object. He therefore moved that Rule 41 be adopted with the addition of those words to clause (*c*).

MR. FANTHORPE seconded.

The resolution was put to the meeting and carried unanimously.

It was also agreed that the same alteration should be applied to the rules dealing with the other grades of membership, the final phraseology to be decided by the Provisional Committee.

MR. FUNCK suggested that designers should come within the graduates class, and be transferred as their positions improved. For that purpose he suggested that the age limit of 26 should be deleted from the graduates clause.

On the latter point there was a general consensus of opinion that the age limit should be retained, and that if a graduate had not qualified for a higher grade of membership by the time he was 26, then he should drop out of the Institution altogether.

MR. MAX LAWRENCE, referring to Rule 44, dealing with Associates, suggested that the words "or shall be a person nominated by an Honorary Member" should be deleted, and that a scheme for Affiliates, on the lines of that introduced by the Institution of Automobile Engineers, should be adopted. Honorary members should be men whom it was an honour for the Institution to have as honorary members, and they should not be called upon to pay a subscription, as would be the case if honorary members were to be firms who must nominate someone to represent them.

THE CHAIRMAN said that was a point which the Provisional Committee or Council, as they had had to call themselves for the purpose of registration, would take into consideration.

MR. MAX LAWRENCE said there should be an honorary member class as well. Affiliates, however, should be firms who could send as many nominees to the meetings of the Institution as they paid subscriptions for. In the case of the Institution of Automobile Engineers, the subscription was 10 guineas. These nominees could not vote, and he hoped that suggestion would have the serious consideration of the Council.

The question of subscriptions was then dealt with. Some members thought it difficult to discuss this until a scheme could be

put before them showing the number of members and the likely expenditure.

THE CHAIRMAN agreed that some statistics of this kind were necessary before the lowest possible subscription could be determined, but there might be some discussion with a view to helping the Provisional Committee to ascertain what they thought could be asked from each class of member. The subscriptions proposed in the draft Articles of Association compared very favourably with those charged by other institutions. It had been suggested that the first thousand members should be admitted without entrance fee. That and other suggestions would be considered by the Provisional Committee, and all that was necessary now was for them to make suggestions as to what was thought reasonable. The expenses to date were about £50, but the members of the Provisional Committee had agreed to meet that sum if necessary. In addition to those present, there had been some hundreds of applications from the provinces for membership.

MR. ATKINSON said he did not think there would be much difficulty in getting a thousand members, and that would give a revenue of about £2,000.

MR. MAX LAWRENCE said experience seemed to show that the membership of institutions went up to a certain point and then stuck. If they contemplated printing Proceedings, it would cost a very large sum of money.

THE CHAIRMAN said the Committee had in mind the idea that *Engineering Production* might be induced to become the official organ of the Institution. The Institution of Automobile Engineers made a similar arrangement with *The Automobile Engineer*, and their printing expenses came down with a run in consequence.

It was then put to the meeting that Rules 53 to 58, dealing with subscriptions, should be favourably considered by the Council.

The proposal was agreed to.

A MEMBER suggested that as the majority of the members up to date had been secured through the publicity of *Engineering Production*, it would be a wise policy to endeavour to secure that journal as the official organ of the Institution.

MR. HONER said he would like an opportunity of expressing the Institution's thanks to Messrs. Iliffe for the assistance they gave in connection with the inaugural meeting last month. They came forward at the right time at no benefit to themselves whatsoever. The publicity in connection with the meeting, and the account of it, took up a certan amount of space in *Engineering Production*, and he asked the meeting to pass a hearty vote of thanks for this assistance.

MR. GERALD SMITH said he would have much pleasure in doing that. He believed that if *Engineering Production* did become the

official organ of the Institution the results would be to the mutual benefit of the proprietors and to the Institution.

MR. H. J. HILL seconded the vote of thanks, which was put to the meeting by the CHAIRMAN, and carried with acclamation.

The Secretary was therefore instructed to approach Messrs. Iliffe accordingly.

MR. ATKINSON said that one reason for forming the Institution was that the production engineer at the present time was not sufficiently recognised. There was no status, and a production man might mean anyone earning anything from 30s. per week to £3,000 per annum. If the production engineer was given a status, as it was believed he would by the formation of the Institution, that must react upon the question of salaries.

MR. MERCER raised the question of the use of initials denoting membership of the Institution. He hoped the Committee had noted that point.

THE CHAIRMAN said that that was one of the very useful suggestions made by Mr. Max Lawrence which had been taken note of for consideration.

MR. ATKINSON said there was one little matter that he would like to refer to. Throughout the meeting that evening reference had been made to the Council. The fact was that the Provisional Committee had been compelled to constitute itself a Council in order to be able to apply for incorporation, but he did not wish it to be thought that the Provisional Committee had formed itself into a Council and was now saying that anything they did the Institution would have to accept whether it liked it or not. The Provisional Committee or Council was subject to the control of the members.

This closed the general business of the meeting.

MR. ROBSON suggested that as the Committee had power to co-opt other members, he would like to propose that Mr. Max Lawrence should be added to the Provisional Committee.

MR. ATKINSON seconded the proposal.

The proposition was carried unanimously.

MR. MAX LAWRENCE, in thanking the meeting, said the reason why he wanted to join the Institution was because he wished to benefit by hearing other people's experiences in regard to production methods.

On the proposition of MR. FANTHORPE, seconded by MR. MERCER, Mr. Robson was added to the Committee.

On the proposition of MR. FISHER, seconded by MR. BUTLER, Mr. Atwood was added to the Committee.

On the proposition of MR. WARING BROWN, seconded by MR. ATKINSON, Mr. Hales was added to the Committee.

It was agreed that the Provisional Committee should have power to co-opt further members at its discretion.

THE CHAIRMAN said the Provisional Committee would revise

the Articles of Association in the light of the criticisms and suggestions that had been made, and would place them before the members at another meeting, the date of which would be announced in the official organ. On that occasion an effort would be made to have a paper read also.

A hearty vote of thanks was accorded the Chairman and members of the Provisional Committee, and the proceedings closed.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting was held at the Institution of Mechanical Engineers on Friday, July 15, Mr. C. F. HAMMOND presiding.

In opening the meeting, the CHAIRMAN explained that he occupied that position merely as a temporary measure as the Chairman of the Temporary Committee which had so far been conducting the affairs of the Institution. He assured all present that there had been a great deal of work in getting the Institution going, but that part of the programme had been completed, and they must now get seriously to work. He need not enlarge upon the importance of the production engineer. The very fact that so many people had come forward and formed the Institution was evidence of that, and also of the need everybody felt for having some medium through which the production engineer could make himself coherent. Until now it had been impossible for the production engineer to work on the lines of the Institution of Mechanical Engineers or the Institution of Automobile Engineers, or other branches of the engineering industry. During the war, however, the business of the production engineer assumed such importance that there was need for a separate Institution, and, as showing the interest that had been taken in the movement, he would ask the Secretary to read the list of names of members so far elected.

The SECRETARY having read the list,

The CHAIRMAN expressed the thanks of the Institution to the Council of the Institution of Mechanical Engineers for their courtesy in allowing the use of their building for this meeting and in putting forward a helping hand to the younger body.

MR. MAX R. LAWRENCE then read a paper dealing with "Production and the Engineer," which appears on the following pages.

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PRODUCTION AND THE ENGINEER.

By Mr. MAX. R. LAWRENCE, M.I.M.E., M.I.A.E.,
Member of Council.

I have been asked to speak to-night on the subject of "Production and the Engineer" by way of inaugurating this new Institution of Production Engineers, at the first meeting.

You have heard from our Chairman, and seen in the Press and our official organ, *Engineering Production*, the various stages of the inception and development of the scheme. I therefore only lightly touch upon this, but I think it will not be out of place for me to state what I consider to be the chief work that can and will be done by this new Institution.

Probably there has never been a greater need in the world for production than at the present. The one important question of the moment is how to find a way out of the deplorable situation in which the country is involved, partly through the unavoidable operation of world-wide causes, but also largely from the three months' coal strike, which has brought about a paralysis of industry.

Every department of national life has been affected. We have produced less for our own consumption, and less for sale abroad, and consequently we have had to buy more, at higher prices, to supply our actual necessities, while we have sold considerably less, and much of that in falling markets.

The consequent drain upon our credit in foreign countries is not yet fully felt, but will be more seriously felt after the harvest, when great disbursements begin.

What this country needs, therefore, is to settle down to a long spell of good hard, conscientious work. There is no easy road to wealth, and the idealists who start the catch cries of "Nationalisation," or "Soviet Control of Industry," etc., as the panacea for all our ills, are all wrong. Wealth can only be accumulated by good, conscientious hard work properly directed. The standard of living can only be raised by providing better means for doing work, and so making the individual more productive.

As our civilisation advances the tendency of life is to become more complex and for individuals to specialise more intensely, so that this fundamental fact becomes perhaps a little more obscure. But although our life is more complex, the essentials have not changed. Man has still to produce to live, and the production of things is still the only source of wealth, and true wealth is still measured by the amount production exceeds consumption. As a great deal, if not the whole of this country's production is more or less dependent upon the activities of the mechanical engineer, we production engineers have a most important part to play in this country's welfare by developing to the utmost the economical manufacture of our engineering products.

This Institution, therefore, would seem to be born at a very opportune moment, and I think we may consider to-day its true birthday.

The rules and Articles of Association and qualifications of membership have all been settled. I feel there is a great potential future before us, and that with the active co-operation of all the members we should get on our feet rapidly, and become in a very short time a strong and healthy body, doing excellent work.

Engineering production is essentially team work. The fitter cannot get on without the turner, and neither can do without the

Mr. Max. R. Lawrence.

designer, moulder, the smith, and the hundred and one other allied trades and professions.

The trend of all invention and design is always to make the individual more productive by employing better machinery and equipment, to perform work with less effort of brain and muscle. In order to do this effectively there must be close co-operation between ever-increasing numbers of people. Every team must have a captain, and a successful captain must command the obedience of his team. In order to do this he must win their respect, and their success is as much dependent on mutual trust, loyalty, and understanding as their capacity to play the game well. Probably, therefore, the largest

factor in successful production is the human element and the power to command respect and win the confidence of others. You cannot get production if you have constant labour trouble.

In order to keep proper co-operation amongst a number of individuals you must make their work congenial. No man can do his best, be he manager, production engineer, or office-boy, unless he feels that he is trusted, and that his efforts are appreciated. This appreciation must go further than providing the necessary £ s. d. for wages. It must also provide him with a certain definite sphere in which he can express his own individuality, and that sphere must be sufficient to allow him to select a definite line of action, however small. He should be able to point to his work and say, "This is mine, see how well I have done it." It matters not how small a portion it is of the whole.

To illustrate my point I will tell the story of the famous organist and his bellows boy. One day after a particularly fine performance, as they were going home, the boy said to the artist: "Did we not play that well, sir?" "We! We! What do you mean?" was the reply. "What had you got to do with it?" Next day, in one of the finest passages, the boy stopped blowing, and when taken to task only asked: "Well, is it to be WE?"

Such stoppages are always disastrous, and often unnecessary, for had the artist recognised that even he could not play without a good bellows boy, he would not have had the stoppage.

Thus production, and therefore the production engineer's profession, is very largely dependent upon the human side of the control of labour. It is necessary to his success that he should thoroughly understand the psychology of human nature in the works, therefore it will come within the province of this Institution to discuss labour matters and other things relating to the employment of the operators in the works.

In the other professional institutions this has always been "taboo." They have catered more for the scientific, or design, side of the profession, and not like ourselves, who intend to deal mainly with the actual making of the products. The subject I know will have to be treated with care, but I see no reason why these matters should not be debated at our meetings, as they have such a large bearing upon production.

In times gone by I am afraid sufficient time and trouble were not always given to this side of production. During the war a great deal of energy was devoted to calling attention to, and dealing with, this subject. Besides what was done voluntarily, a department was created at the Ministry of Munitions, whose sole duty it was to look after the welfare of the employees in the various works. No doubt, due to overkeenness and inexperience, mistakes were made, but on the whole excellent work was done, which has made a permanent advance on this side of our production problems. There is hardly a works of any size to-day which has not established a more or less effective means to this end. As time goes on the channels so provided will be widened and deepened, and will enable a more effective human touch to operate in our industries, with the attendant benefit to production.

There are a number of people who for more than half a century have preached that the machine is the enemy of man, and the triumph of machinery the degradation of the worker. The skill of the crafts-

man, we are told, has been destroyed by machine tools and machine processes, and in that destruction the worker has lost not only pride and pleasure in his work, but self-respect. The man on the machine becomes himself a piece of machinery—a living tool.

This theory has long been popular with this certain set, and has been urged with great literary power by Ruskin and William Morris. They, however, have only seen one side of the story, and quite forgot, if they ever knew, that a man can take pride in, and exercise more skill in, devising and running fully automatic machinery, with which he can make more goods in a week than he could in a lifetime by exercising his handicraft in the old way.

Now the function in life of the production engineer is to put his best brains, energy, and skill into his work. It is his profession and life's work to see how he can adapt the means at his disposal to the best advantage, and manufacture pieces with the least possible expenditure of human effort, and therefore at the cheapest possible price.

To me there has always been a great joy in devising better means to this end.

This method of evolution brings in its train other things, and the designer is enabled to use pieces in more complicated shapes which previously were ruled out on the score of difficulty and expense. True, it becomes increasingly difficult to find a fitter who can use a hammer and chisel with minute precision, and fit a key successfully, but these methods of shaping steel have been superseded, and designers can no longer afford to use pieces that have to be shaped in this way. Keyways have been replaced by splines, so that key fitting is done much more perfectly on precision machines, and therefore much more economically.

In this way the engineering industry has developed from small beginnings, when metal first began to be tooled accurately, to the present position, where a large industry is engaged in making all manner and kinds of pieces, both large and small. The profession of the people whose business it is to control works and employ workmen has therefore gradually developed, and there are few mechanical engineers to-day who have not specialised, some more and some less intensely. All who have had experience of making a quantity of pieces alike (and many have had their first experience during the war), now realise that very different methods have to be employed when quantities are large from those suited to making only few.

It has been patent to all concerned in manufacturing a number of pieces, that the cost of production with the help of special machinery and jigs, tools, etc., can be very much reduced and so cheapen the product, in some cases beyond the imagination of the experts concerned.

Now the development from making a few to manufacturing in quantity has normally to proceed by easy stages, and is usually the outcome of a gradual development. The methods employed have to be moulded as the circumstances arise, and always with a limited amount of capital. The old proverb that "One must learn to walk before one can run," applies very aptly to all engineering undertakings, and it is the art of successful development from the small to the greater quantities that really affects the well-being of most engineering concerns.

This development has modified the duties of the *personnel* engaged

in the various works, and I think the title of production engineer comes from the States. There, because of the fewer number of trained mechanics and larger population, intensive manufacture has made greater progress.

Although this Institution has adopted this name, it will, of course, be understood that the membership must be drawn from, and include, all engineers and others engaged or interested in engineering production.

We production engineers whose business it is to deal with all stages and phases of such development in many different kinds of engineering products, thoroughly realise what a fine art and sound judgment is called for in the process. Many men who are more or less captains of industry, or, anyway, directors of engineering concerns, I am afraid do not always realise, and recognise, the men whose judgment they rely upon to steer them successfully from small into big outputs.

During the war it was necessary to multiply a great number of pieces in a great many different ways, and in consequence, a large number of people had to learn at high pressure how to develop works and to get production. Great works were enlarged or built for making shells and other war material, plant was gathered from wherever it could be obtained, and the operators and people at the works were drawn from all classes of the community. A great many creditable performances were put up, but in quite a number of instances more or less bad failures were made, chiefly because the stages of development were not properly organised. The conceivers of schemes imagined that by equipping a factory and putting down plant, and getting somebody to make tools, and throwing a whole lot of people into the works, all that was necessary had been done, and were somewhat rudely surprised that things did not happen as anticipated. In the majority of these cases the production engineer or production specialist was conspicuous by his absence, or if there, was not allowed sufficient power to deal with the detail of the organisation which he knew was necessary to success.

Some of us have suffered by being prevented from doing what we knew to be right from an economical point of view simply because our superiors had not sufficient confidence in our judgment.

When a good man is faced with such a set of circumstances he looks round for means of demonstrating conclusively that he is what he knows himself to be—a good man whose opinion is worth following—or he seeks to find out where he is at fault.

It is this thought which underlies, and really I believe is responsible for, the birth of this Institution, and it is hoped that it will provide a ready means, by the reading of papers, and taking part in discussions, for men to help each other by the exchange of ideas, and by the expression of opinions to deal more successfully with their problems.

It is not essential, in my view, that a man should necessarily possess a first rate scholastic education to be a good and sound production engineer. There are certain characteristics, which are mostly born in a man, which fit him when suitably educated for holding such a post.

Very few of the larger institutions, such as the Mechanicals or Automobile Engineers, cater for such people; they all deal with the more scientific or designing side of the profession, and require that

their members should have a high standard of general education, that is to say, have been at a public school, or capable of passing the matriculation examination at one of our universities.

Also, the scheme of the larger institutions, until quite recently, with the exception of the Institute of Electrical Engineers, has been to centralise, and to acquire premises and hold meetings chiefly in London, and as a result, out of their vast membership, only a very few can take part in their meetings.

I believe I was one of the first to realise how this stultified and curtailed their activities, and so I started a branch of the Automobile Engineers at Birmingham. This proved a great success, and when I left Birmingham for Manchester I started a similar branch there. Now there are branches in Coventry, Glasgow, and Wolverhampton, in addition, where meetings will be held regularly.

The Mechanicals have soon followed suit, and now papers are read again in the provinces, or some papers at the local centres only.

It is the intention of the Council of this Institution of Production Engineers to carry this much further, and as you will see by the circulars, they hope that it will be possible to develop centres in all the large engineering districts, so that it will be feasible for members to meet frequently, without incurring undue travelling, time and expense, to exchange ideas and keep abreast of the times.

When I was serving my time I was a member of the Derby Engineering Society, which had a membership of about fifty. The members were lads like myself, serving their time in the town, and we each made it a point of honour—and certainly it was our great pleasure—to attend every meeting. Many of us read papers, and although no doubt they were not of very wide interest, yet they were intensely interesting and instructive to ourselves, and discussion on them was very keen and enjoyable.

If we are able to get a lot of local centres who can meet regularly in this way, with occasional exchange of visits between towns, I feel sure that a very live, prosperous, and healthy Institution will be built up, and do a tremendous amount of good work.

We have been fortunate enough to secure the goodwill of an official organ in *Engineering Production*, and the Editor will publish notices and papers, and in this way a large number of people will be able to obtain a hearing for, and a record of, their ideas in a form which will be very useful to others, and certainly to themselves.

One good piece of work this Institution can perform is to help define what a production engineer is, or should be. During our first meeting we had many expressions of opinion, and they were so varied that it almost seemed that every engineer present attached a different meaning to the term. It was, however, generally agreed that he has to standardise operations and processes. The duties of a works manager, machine-shop superintendent, foreman, etc., are usually fairly clear, but the production engineer has as yet no generally understood definite status.

It will be useful at this stage to have an expression from this meeting as to what his duties might be, and I hope that what I am going to say will create a good and lively discussion. On account of the varying size of works, their locality, and the different industries upon which they are engaged, it will never be possible to get an exact definition, but by collecting together now and in future various

opinions, a status will be gradually built up which in the course of time will become generally recognised.

I have therefore set out a list of duties to start a discussion, well knowing that no one in this room, including myself, will think them altogether suitable. I hope, therefore, that everyone will speak and give us the benefit of his ideas, and so help forward this work.

1. The production engineer should report direct to the works manager or works superintendent.

2. He should have power to decide what machinery was to be used, and how the various pieces were to be tooled.

3. The jig and tool designer should be under his direct orders and report fully to him.

4. That the rate-fixing office for setting piece prices or bonus times should have to obtain his approval in detail on these matters.

5. That the labour master who hires the operators should look to him to settle the rate of pay before lifting any standard rate above the normal.

6. That the fitting and assembling shops should have to bow to his decision as to methods and processes adopted to complete the product.

7. That he should be responsible for seeing that a sufficient number of jigs, tackle, tools, and gauges are provided at the right time to reach and maintain the quantities contemplated by the manufacturing programme.

8. That he should not be responsible for the progress of work throughout the works, and for attaining output.

9. That he should not be responsible for the purchase of plant other than making recommendations to his superiors when called upon to do so.

10. That he should not be responsible for discipline, the care or supervision of the use of jigs, gauges, and other special equipment he has provided, or for their correct use.

11. That he should not be responsible for quality other than seeing that adequate means are provided to enable the pieces to be made with sufficient accuracy to pass the viewer.

12. That he should not be responsible for transport of material in the works.

13. That he should not be responsible for wasters, or other similar matters except in so far as they are affected by the design of the equipment provided.

14. That he should not be responsible for any booking, manufacturing records, or accountancy.

Now, these fourteen points, half of them negative, cover a fairly comprehensive ground. They are set out in this form in order that they may be criticised.

Many works carry such an officer, but he is often styled "Assistant Works Manager."

Many of the duties set out in this schedule are performed by different individuals in different works. For instance, in some works the rate fixer is paramount in regard to fixing rates, and need not consult either the foreman or superintendent. In other works there is no rate fixer, and the price fixing is done by the foreman under the supervision of the works manager direct.

In dealing with his duties it is essential that a man exercising the powers as suggested in these fourteen points should, of course, co-

operate with the staff. We presume, of course, that a production engineer is always competent and tactful, and that, therefore, he will, as a matter of course, consult with, and be guided by, the foreman and superintendent with whom he works, and that while it may be true that he has power to act without consultation, he will consult where necessary, and carry along the mind of those who have to work the plant and get out the quantities, and generally make things happen with the means provided by him.

Now the object of this paper, as I daresay you will have appreciated, has been to put into words my ideas as to some of the activities that this Institution will pursue, and I believe that by dividing its meetings and meeting places into a large number of sections, so that the travelling expenses and time of the members are not wasted, the meetings will be small and therefore less formal, and a more ready and fruitful exchange of ideas can take place, to the benefit of all concerned.

The Council hope that members in each district will come forward and form a centre, and it would be helpful to have an expression of opinion from this meeting as to how large, or rather how small, the number should be. I personally think that if there are twenty members in a town or district that should be sufficient.

These centres would arrange their own meetings and invite other centres to joint meetings. Notification of these would be given in the official organ, so that any other members interested, and not resident in the district could attend. This would be very nice for those who travel, as if there were a meeting on it would be a good way of spending an evening in a strange town.

I hope I have not trespassed too long upon your patience, and that we shall have a good discussion, which will help to guide the Council in developing our programme.

THE DISCUSSION.

THE CHAIRMAN, in opening the discussion, mentioned that the financial resources of the Institution were not yet such that it had been possible for the paper to be printed for the meeting. It would, however, be reproduced in *Engineering Production*, which journal had kindly arranged to publish the Proceedings of the Institution. Dealing with some of the points in the paper, he said he did not quite agree with the view that intensified production tended towards the degradation of labour. His opinion was that labour need not be degraded unless it deserved to be; no matter how commonplace the operations might be, there was always a means of getting a little bit more out of the job, and given enthusiasm, that would apply to almost all operations. There was no necessity for the degradation of labour if only labour would rise to the possibilities that existed around it. A great deal could be done in that direction, however, by the sympathetic treatment of labour by those in charge, in many ways. A point mentioned in the paper which required emphasis was the standard of education of members of the Institution. The production engineer might come just as much from a council school as from the large public schools, because the actual suitability of a man to be a production engineer did not depend so much upon education, within limits, as upon an inborn suitability for such work. The production engineer was born and not made. A matter which deserved more attention was the careful selection of works managers. In most cases they ought to be production engineers before attaining the position of works managers. Generally speaking, the production engineer was the man to whom the works manager delegated a certain amount of work which he himself would otherwise be entirely responsible for, and he personally could not dissociate the works manager from the production engineer. The latter was only one step down the ladder from the former, and was qualifying himself for the post of works manager eventually. One point not mentioned in the paper was the necessity in every organisation for a works costing department as quite distinct from the ordinary accountancy. That work should be entirely independent of the production engineer, but he should have access to all the records of the works costing department, otherwise he might easily be misled into advising the management to buy plant which was totally unsuitable from a cost point of view.

MR. H. C. ARMITAGE, member of Council, who was unable to be present, sent a letter which was read by the Secretary. In this he said:—Mr. Max Lawrence is suggesting that the "production engineer" has very definite and fixed duties. These duties I think have been drawn much too small for a large works, and they are inadmissible in a small works because they would have to be covered by the plant engineer, tool engineer, or works manager, on account of staff expense. For the purposes of the Institution we must con-

sider all works administrative positions as being those of production engineers—even to that of a chief inspector who has nothing to do directly with production, but can exert as much influence on the production as the shop management. I am pleased to note that the duties of a production engineer generally accepted in this country are not put forward by Mr. Lawrence. I mean particularly where the production engineer governs material supplies, outside orders, progress of work, and balance of stocks, etc. The suggestions are, however, open to criticism in several minor points, and since they are inapplicable in a small works, they must be discussed purely as a large works proposition. The most important omission is work planning, and its necessary connections. Taking any line of engineering manufacture there are certain elements to be fixed as a preliminary to the actual productive work. They are:—1. The design of the product. 2. The design of methods to produce the product. 3. The design of tools to produce the product. 4. The fixing of time allowances to produce the product. Functions 2, 3, and 4 are obviously those that fall to the lot of the production engineer. He would, therefore, not be in direct control of any productive labour in a large works. Under function 2 he would have to (*a*) cheapen product designs or alter them to suit workshop conditions where practicable; (*b*) state all machining allowances; (*c*) fix all working limits and tolerances; (*d*) add chucking and locating facilities; (*e*) specify the most economical forms of raw material; (*f*) allocate parts to shops; (*g*) separate the product parts lists into detail assemblies, sub-assemblies, and final assemblies. Under 3 the production engineer would have charge of the tool design office, tool schedules, etc. Under 4 he would have charge of the rate fixing, operation setting, and, as a consequence a great deal to do with estimating and costing. In a factory certain results have to be achieved. The production engineer estimates for these results, and adequate costing is only obtained by the comparison of estimates with the results. Cost figures are utterly useless unless there is comparison basis. There are two other secondary productive questions which grow out of those already stated, and these are the effective measurement of the productive capacity of the factory, and the regulation of the quantity of labour required to obtain a given output from the factory. It is highly important to have a figurative basis on which to base these two important items. The production engineer must be in a position to handle relative costs effectively, and perhaps not one costs department in a hundred can fill his requirements. A typical problem, for instance, would be to decide whether a certain class of steel with several heat treatments could be used more economically than a more expensive steel with less heat treatment. In fact, nearly all matters of works policy can be dealt with on a comparative cost basis, and approximate figures substituted for the usual broad area judgment that takes place in many large manufacturing works.

Mr. J. D. Scaife (Newark-on-Trent) said that whilst he was in general agreement with the points laid down in the paper as representing the duties of a production engineer, yet it was necessary to vary the duties according to the size of works and the class of product. It might be found that they had a man who qualified as regards 75 per cent. of the procedure laid down in the paper, but on trying to find one who qualified as regards the remaining 25 per cent., they might get one who

failed as regards the 75 per cent. Indeed, it would be very difficult to find a man who would fulfil all the qualifications laid down in all circumstances. Therefore it was necessary to get down to concrete cases, and deal with them on their merits rather than to deal with the matter in a general way. Nevertheless there was a great advantage in having an address of this general character at the outset of the work of the Institution; at the same time, the Institution must later get down to the discussion of definite cases. With regard to Point 2 in the paper, he presumed the author referred to machinery already installed, and that it did not apply to new machinery, because a change of machinery which might make a big difference to the profits ought to be subject to the decision of the board of directors. It would, of course, depend upon the size and nature of the works, but in a large works, where even only a small change of machinery was a very important matter, then it should be a matter for the board. Dealing with those points of the fourteen with which he, Mr. Scaife, disagreed, under No. 10, Mr. Lawrence suggested that the production engineer should not be responsible for discipline, but in that case how was the production engineer to get production? Who was going to control the workers if not the production engineer? He agreed, on the other hand, that the production engineer should not be responsible for quality, but should content himself with seeing that the work was turned out according to the limits on the drawings, which came from the designer and drawing office. Again, the question of whether the production engineer should handle transport was one depending upon the size and nature of the works. In a large works, the progress manager should handle that. At the same time he had heard arguments against that, because a progress manager might be so slick in getting the work from one department to another that a job might turn up, say, in the assembling department with several operations missing. As to No. 14, he agreed with the Chairman that there should be a works accountant whose record should always be available to the production engineer, otherwise he would not be aware whether the piece rates were being worked to, and whether a man was drawing a bonus or not. It was the function of the works accountant to supply that information.

Mr. Raymond Mitchell urged the necessity for impressing upon all workmen the need of improving their craftsmanship, and he mentioned some instances of how he had used this argument successfully in dealing with men whose work was by no means creditable. In this connection he compared the German motor-car lamps of Robert Bosch with those of the firm regarded as the best maker in this country. The German lamps were beautifully finished, and he had obtained two for £5, whereas he had had to pay double the price for the best English lamp, which was very much inferior in quality and finish. The work of the production engineer was to see that the very best work was turned out at the lowest price, and he did not regard it as commercial to turn out inferior work at a low price. The question of improvement in British craftsmanship would have to be kept fully in mind, because he was convinced we were capable of turning out articles which would be unrivalled in the whole world.

Mr. Teddington said he thought the Institution was badly needed. The subject dealt with in the paper was a very broad one, and it was difficult to narrow it down without dealing with specific cases. Dealing

with the subject broadly, it seemed to him that there were four essentials for the production engineer. First, he must have accurate knowledge for his job; second, tactful ability to deal with the human element, with which he came into such close contact; third, imagination, so that he might have a sort of prophetic vision of what was going to happen after he had laid out his first batch; and, fourth, there must be sympathetic help to the men working with him, in order to ensure success. When we came to details, everything depended upon the size of the works and the nature of the article being produced. He hoped, therefore, that the Institution would on future occasions bring forward specific cases which could be dealt with. Even before the war there was always a man knocking about the works who carried out these duties, but he had never had any official standing, and he hoped the Institution would be successful in bringing about an improved status for the production engineer.

MR. HALES said that as a works manager who had previously been a production engineer, he knew some of the difficulties of the latter position in large organisations, and he felt for all those holding that position whose duties were not clearly defined. In his opinion the production engineer should be the accepted works reference for all matters relating to production. To begin with, he thought the production engineer should have charge, in conjunction with the chief designer and head of the drawing office, of the first check over of drawings, *i.e.* detail drawings, with a view to modifications, so long as these alterations did not materially affect the design. Next there was the process of operations, which it was essential the production engineer should control. This duty was often fulfilled by the rate-fixing section, but he felt that the lay-out of plant, the processing, and the rate-fixing, were essentially things which the production engineer should control after the drawings had been put in order for the most economic manufacture. The times should be fixed by time-study methods after the style of the American planning department, and arrangements should be made, in processing the work, to state the jigs, tools, fixtures, and gauges required, together with the machines on which the operation had to be carried out. That was necessary before manufacture was started at all because the estimating department could not give accurate figures unless the manufacture was processed accurately, and a time given for the various operations. The same applied to the buying department, which could not get to work accurately until the process of manufacture had been decided upon. It was also necessary that the production engineer should have access to the costing and records departments, and not control them. He should, however, control plant purchase, because nobody was in such a good position to decide what plant was required to give the best results. Where the size or form of the piece warranted it, operation drawings were the best, because then the operator could go straight on with the work without any further assistance. That was an important point. He disagreed with the author on the question of the control of transport, which was a very important item in processing operations, and should be under the control of the production engineer. It was often more important to look to the transport facilities during the various operations than to speed up the job itself. It was often found that an assembly unit required a few steady pin-holes put in at the last moment, and perhaps it had to be sent from the assembling department to the drilling department, a

quarter of a mile away. The drilling and reaming might take two minutes, and the transport a quarter of an hour or longer. Thus transport was quite an important item in production, and should be taken care of by the production engineer.

Mr. Gartside said he would like to hear the views of the costing department and the heads of the other departments if it were seriously proposed to put them under the production engineer. It would require a superman to do all the work that the various speakers had suggested the production engineer should do. His idea of the production engineer was that of a man with a roving commission to cheapen production, who was not head over anybody, but was responsible to the directors. He must be a man able to work in co-operation with all departments, and must have been through all the various departments himself before being given the job as production engineer. The only broad way to look at the matter was to say that the function of the production engineer was to cheapen production. He did not agree, for instance, that he should check the drawings, because, to begin with, he would need a whole staff to do that. The chief designer and head draughtsman must be responsible for the design in the first place, and the production engineer responsible for turning out the parts according to the drawings. An important part of the production engineer's duties would be to sift the various ideas put forward by the men for improvements in methods of operation, and in that respect he could do a great deal in encouraging men to take an interest in their work.

Mr. G. W. Webb asked if the Institution was a body to consider production methods or was it to be a glorified trade union for the peculiar man, who practised a peculiar calling, and was known as the production engineer. It seemed to him that every engineer who was making something was a production engineer. He imagined it was the intention that the Institution should study productive methods and endeavour to improve them from the point of view of cost, quality, and quantity. There was a big margin between the Rolls-Royce, which was made for quality only, and the Ford, which was made for price only, and in that field the Institution could be of very great benefit. It had always seemed to him that the production engineer was the most valuable man in the world, and he had been responsible for a very great deal of the progress in recent years, and if the Institution looked at the matter from the point of view of improving productive methods, then it should do valuable work.

Mr. Sholl, speaking as one who was trained in this country, but had spent a great deal of time in the Overseas Dominions, and was returning there again after a visit here, said he was surprised to notice how the technical institutions in this country omitted to consider the human element in industry. There was an enormous field for work in this connection, because it could not be over-emphasised that Great Britain could not feed herself, and unless the way was shown for increased exports of manufactured articles in order to pay for imports of food, we should be starved out. To bring that fact home to the workers in order to increase output, would alone justify the existence of the Institution. Incidentally, he commented severely on the lack of salesmanship on the part of many British firms endeavouring to deal with the Colonies, and concluded by saying that the Colonies would not buy goods merely because they were British.

They must be of the right quality and price, and suitable for the service in view.

A VISITOR frankly said he could not hope to fill all the qualifications for a production engineer that had been put forward. A superman, indeed, could not. He hoped the qualifications for membership of the Institution would not be too closely defined, otherwise many would not be eligible. The Institution should exist for the exchange of ideas from practical men engaged in the workshops, be they foremen, superintendents, or works managers, or what were called production engineers. It had been truly said that the qualifications for a production engineer varied in every case, and they could not define on a broad, general basis what his duties should or should not be.

MR. H. ATKINSON (London), said there seemed to be some misunderstanding as to the *raison d'être* of the Institution, although it had all been discussed, and he thought settled at the earlier meetings. This was not an institution for production engineers, but an institution for production, and the aim was to improve the status of the production engineer. At the present time he had hardly got a status at all. Production, as such, went far beyond engineering. The whole world did not live on engineering; it did not eat engines. There was food and clothing and many other things, all of which came within the scope of the production engineer. He had been hammering at this ever since the first meeting, and the basis of the Institution had been broadened to include any man who was engaged on production, no matter what it was. Whether he had any education or not, such a man was eligible for membership. Although they could not give a definition of a production engineer which would cover all industries, it would be possible to deal with industries individually, and to say what the production engineer should be able to do in these particular cases. When they began to do this they would be getting on.

MAJOR WRAITH said the usual definition of an engineer was a man who could do for £10 what any fool could do for £20. He would define a production engineer as a man who could do that for £5 and do it at twice the rate. It was quite obvious that the qualifications of a production engineer would vary according to the class of works and the type of product, and he instanced telephones, motor-cars, and hydraulic presses, the manufacture of which had very different characteristics.

MR. MAX. LAWRENCE, replying to the discussion, said he had got the kaleidoscope of opinions he had asked for in the paper. He had not suggested that he himself believed that machinery degraded labour, but merely that some people thought so. Personally, he did not. There were many opportunities for a workman in devising better means for doing his work even when dealing with machinery. More of the 14 points he had set out had been agreed with than he had expected would be the case. The list of points he had put forward cut the production engineer out of all executive work. He was responsible for providing the means, but not controlling the *personnel* or flow of work. Whether that was good or not, he did not know. Mr. Armitage was the person who had taken that matter up, but then he had given it a qualified blessing by saying it would apply to a large works. In his own control of works he had always divided the work in this way. Possibly when the subject was debated again they would agree more upon what a production

engineer should be. Major Wraith had put it in a nutshell, and the qualifications would vary with the type of works and product. Even that had advanced the matter one stage towards the ultimate definition of a production engineer. As Mr. Scaife had also said, it was necessary to fit the man to the job, and it would be necessary to know the precise duties in each case, and one of the good works the Institution could do was to help to define these positions. These discussions would not only educate themselves, but their employers and superiors. Mr. Mitchell had illustrated part of the danger he wished to refer to, viz., that we do not live alone in the world and that if we do not work hard we shall be in "Queer Street." The speaker who referred to the qualification for membership must have missed all that had appeared in the Press, where the objects of the Institution and qualifications for membership had been clearly set out already. He was glad to have the agreement of the speaker from the Colonies with regard to the human side of industry, because, if anything, that was the largest side of the production problem. If the men were disgruntled they would not do their best work.

THE CHAIRMAN intimated that *Engineering Production* would be pleased to publish any comments from those who had not found an opportunity to speak in the discussion.

Votes of thanks to Mr. Lawrence and to the Council of the Institution of Mechanical Engineers closed the meeting

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COMMUNICATIONS.

I was very pleased to see the human note struck by Mr. Max Lawrence in his very able paper.

A production engineer having, as he does, his finger on the pulse of shop-life must sometimes reflect on the fact that the inventive effort that he is constantly bringing into play towards higher mechanical efficiency will, in spite of the assurance by Mr. Max Lawrence, lead to degradation of skilled labour. I think that this point was very well illustrated by the previous speaker in relation to the girl who had been employed on a small capstan lathe for the past nine years making one small part of an electric switch.

Having held the post of production engineer, I quite appreciate the fact that the plant and machine tools necessitate the investment of a large amount of capital, and therefore must be kept working at full pressure in order to justify the initial outlay, the cost of foundations, depreciation, and many other charges that help to form the machine hour rate.

But in the constant effort to increase the mechanical efficiency of the various machine tools it does seem that we are apt to lose sight of the fact that the operator should receive very careful consideration. The value of the skilled worker to any concern is greatly dependent on his past experience. The higher the mechanical efficiency of the shop, the less becomes the power of imitation, which should, and does, play a very prominent part in the development of the young people we have in the shops, and from whose ranks we draw our best workers.

This is a problem which may be rather out of the scope of the paper, but it struck me that it was a very interesting point on which I should be very glad to hear the views of Mr. Max Lawrence.

With reference to the question of the production engineer having admittance to the cost records, I think this is a question that can only be definitely settled by the size and the nature of the work to be carried on in the establishment.

In a shop carrying out general work the production engineer will necessarily play a prominent part in prices arrived at in any estimate that has to be submitted.

On the other hand, in concerns carrying out highly specialised products he will, of course, be able to get all the information that is necessary for him from his rate-fixing and bonus department.

Sutton. H. MARSTON, M.I.P.E

I was very interested in Mr. Lawrence's paper, published in *Engineering Production*, and was very sorry not to be able to be present at the meeting.

The author's point that "engineering production is essentially team work" is a saying that is not sufficiently recognised. It is a phrase which is often used, but fails to find expression even by many who use it.

It is a difficult matter to attain, but the running of a factory in

which it has been accomplished is so smooth as to give the impression that something is missing. Something *is* missing, and that something can very well be done without, though it is difficult to appreciate that the missing quantity is the element of distrust which so often exists between the various departments of the works.

It should not be forgotten that the team and its work include the workman as well as the staff.

I think it is generally conceded that the term "Production Engineer" comes from the States, and I am afraid that this very fact has assisted in discrediting it.

The name calls up visions of conveyors, elevators, and all such gear, which is by no means the only part of production engineering, although a very important part of it. I think it is the thought of this sort of thing that has discouraged many people from entertaining the notion of employing an engineer who was specially skilled in cheap production.

The fear of having to sink a large amount of capital in moving staircases, etc., is quite a common one. This sensation must not be confused with the dread of scrapping obsolete and useless plant and replacing it by up-to-date appliances.

The production engineer's job mostly begins when he receives the raw material, in whatever form, from the stores. It very often happens that the patterns or dies have to be altered in order to accomplish the desirable end in production. A great deal of work and time might be saved if a drawing of the part was put before the production engineer before a single piece was cast, stamped, or otherwise turned over to him as raw material.

The planning of the operations is a matter requiring very careful consideration, and to my mind the general lines of the proposed method of production should be discussed with the heads of departments and foremen before jigs and tools are put in hand, the works manager to be consulted for approval of scheme. It is possible, even on a small production, to split up operations to their simplest forms and effect very considerable savings.

In regard to point 8, I think that the production engineer *should* be responsible for the progress of the work; in fact, as he will constantly be moving round the shop, observing the methods of production and contemplating improved methods, the progress side of the work will automatically come under his control. Further, working from the view room, through which, or under whose influence, the whole of the product will lie, it is easy for him to note difficulties and troubles that arise in the course of manufacture.

In regard to point 10, discipline, of course, is a matter for the foremen, who should operate direct, but who, nevertheless, will be subject to the production engineer. His presence in the works on his rounds should have a steadying effect and be a very valuable help to the foremen.

In regard to supervision and use of all jigs, gauges, etc., I consider that this is definitely a part of his duty, as he has been responsible for their design and should be the one who best knows how they should be used. Many jigs and special tools are not used to their full advantage because the man who has been responsible for their design has no power to say how they should be used. Human nature being what it is, many good methods are not used because the user or his immediate superior are not aware of the value of

the original idea or its application. In this connection it should be noted that no jigs or tools should be made without the approval of the production engineer. This sounds childish, but let any works manager go carefully into the matter in his works, and he will find instances of this which inevitably give him trouble.

Point 11.—The production engineer's responsibility in regard to quality should end with a demonstration that the means which he has provided are sufficient for the maintenance of the quality. I consider that the progress department should be directly responsible to the production engineer, and in order to avoid complications I have personally found it convenient to create a works office which acts as works costing department, "not to be confused with accounting," progress, and general works routine. I have found that this office, working in conjunction with stores, and using a very simple system, not involving a great deal of paper, is the most economical way of running the internal works system.

As stated, many works carry such an officer, usually called the assistant works manager, and in fact the production engineer is the assistant works manager, except in very big works. As this post, however, is usually regarded as a step towards that of works manager, and as the works manager himself should be a competent production engineer, it becomes very largely a matter of a name, more particularly as in all his activities the production engineer will be answerable to the works manager, who should in turn accept responsibility for his actions.

J. BELL, M.I.P.E.

81, The Grove, Wandsworth, S.W.18.

The excellent paper read by Mr. Max Lawrence at the opening meeting of the Institution of Production Engineers, together with the discussion which followed, has already done much to clear the air and pave the way for a better understanding as to the status and duties of a production engineer.

In the past this position, with its immense possibilities and potential influence over production, has been sadly neglected, chiefly due, perhaps, to the air of ambiguity that has surrounded the title and to the fact that until the Institution became an accomplished fact no organised attempt had been made to establish a clear definition and demarcation of the duties and responsibilities attaching thereto.

By some people the object of the Institution has already been seriously misunderstood, and it has been suggested that the creation of an entirely new official was aimed at, thus adding considerably to the already heavy burden of administration.

Such an idea is, of course, quite wrong, and it should be clearly understood that in most cases, and when fitted for the post, the duties will fall upon the official known at present as "assistant works manager."

Although there will always be some controversy in regard to the exact limitation of the duties of the production engineer, it seems to be well agreed that the position is a most important and confidential one, calling for very special qualities, including tact, organising ability, a very broad knowledge of detailed design and modern manufacturing methods, and should be second only in authority to the works manager.

One very noticeable omission from Mr. Lawrence's paper was

any reference to the relationship of the production engineer to the drawing office—a point, however, which was definitely raised by Mr. Hales, bringing forth a disagreement from Mr. Gartside, thus opening the way for further discussion.

It is in the drawing office that the very foundation of economical production should be well and truly laid, and for this reason it is highly desirable that the production engineer should keep in touch with the drawing office in a consulting capacity during the progress of a new design, and before the detail drawings are issued to the works he should examine these very closely from a manufacturing standpoint, and any questions raised should be decided by a committee formed of the heads of the various departments concerned, and presided over by the works manager or chief engineer.

In the columns of *Engineering Production* this question of detail design and its influence on economical production has already been raised, and it should be the aim of the Institution to hammer this point home, thus securing a higher degree of efficiency in the drawing office and a closer relationship with actual manufacturing conditions.

In order to attain this end, draughtsmen should be encouraged to come forward and join the Institution. The drawing office would then provide much useful material for the supply and training of future production engineers.

E. F. HOSSACK, M.I.P.E., A.M.I.M.E.
109 E, Clyde Street, Helensburgh, near Glasgow.

Passage of time prevented me from entering into the discussion upon the paper read before the Institution of Production Engineers by Mr. Max Lawrence, M.I.M.E., M.I.A.E., on Friday, July 15th. Under the circumstances, I hope you will permit me space in order that my views may reach those who will read the account of the meeting and the wide variety of opinions expressed by many present.

Mr. Max Lawrence certainly provided food for discussion when he attempted to define the status of a production engineer, and my sympathies are certainly with the gentleman who, towards the end of the evening, asked if the Institution is to be a technical society or merely a glorified trade union.

It will be conceded by all those present that the position of a production engineer "all depends." For instance, in a small works he will undoubtedly be the works manager, whilst in a works of the largest size he will be an official under the works manager responsible for the production of one particular department, in which case there will be one in the foundry, another in the machine shop, yet another in the erecting shop, and so on.

Any attempt to impress the engineering world with our importance by propounding a definition is doomed to failure; we must prove by our papers and discussions that those connected with the Institution represent the best brains in the industry, capable of translating drawings into finished articles of the quality demanded at the cheapest rate.

Having proved ourselves, recognition will follow as a matter of course, and "M.Inst.P.E." will be the password to the best positions in the works.

Hy. MANTELL, A.M.I.P.E.
114, Drakefield Road, Balham, S.W.17.

THE
INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting of the Institution was held at the Institution of Mechanical Engineers on Saturday, September 17th. The President of the Institution, Mr. Max R. Lawrence, occupied the chair, and the Minutes of the previous General Meeting were read.

After making some explanatory remarks regarding the objects and formation of the Institution, the President introduced Mr. J. D. Scaife, Works Manager of Messrs. Ransome & Marles Bearing Co., Ltd., of Newark-on-Trent, who then proceeded to deliver a paper dealing with the " Ball and Roller Bearing Manufacture."

At the close of the paper a valuable and interesting discussion took place, in which a considerable percentage of the 42 visitors and members took part.

Votes of thanks to Mr. Scaife and his assistant, Mr. Richardson, and to the Institution of Mechanical Engineers for the loan of the hall concluded the proceedings.

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BALL AND ROLLER BEARING MANUFACTURE.

By Mr. J. D. SCAIFE, Member of Council and Works Manager, Messrs. Ransome & Marles Bearing Co., Ltd., Newark-on-Trent, assisted by Mr. C. G. H. Richardson, B.Sc., A.R.C.S., A.M.I.C.E.

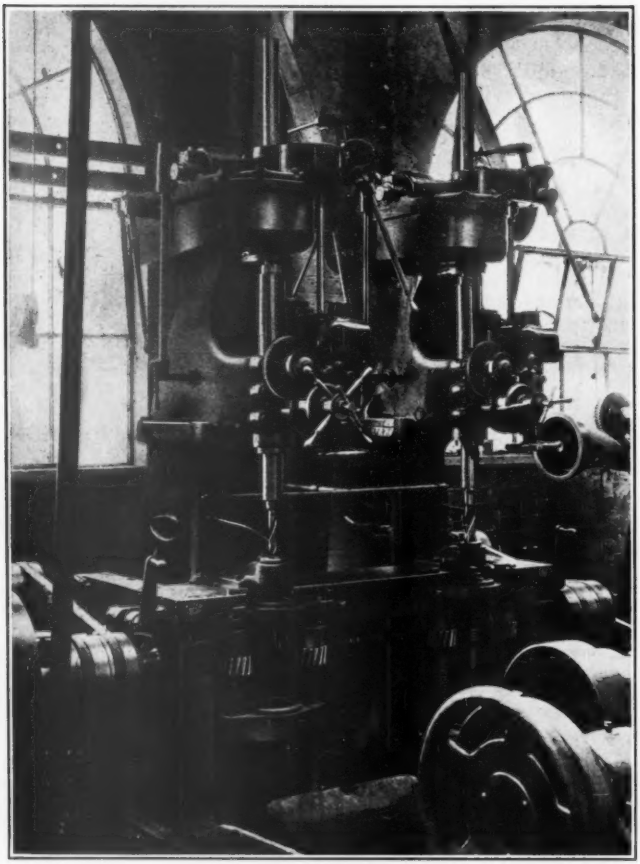
General Remarks.

In commencing a paper on the subject of ball and roller bearing manufacture, the writer would like to suggest that for its size and cost there is probably no other product which calls for the same degree of engineering skill.

Metallurgical, manufacturing and organising sciences must all be exercised to the highest level obtainable in this industry. The raw material supplies the steel manufacturer with his greatest problems; indeed, in spite of all precautions being taken, which experience has shown to be necessary, it is no uncommon thing for the whole consignment from one cast to be returned as faulty, the faults being frequently only discovered after the finish grinding of the tracks. Defects which are usually met with in steel for general engineering products do not occasion the bearing manufacturer much trouble, for they are usually noticed in the rough machining of the material, and no further work is done on the defective consignment. The faults which cause the most trouble are such as would not be looked for in any other product, being very fine hair lines discernible only by an experienced viewer and then not without the aid of a strong light.

On the manufacturing side of the industry, the writer would claim, after many years of experience of mass production, that manufacturing science of the very highest order is required. The external dimensions of ball and roller bearings, outside and inside diameters, and width, are made to published tolerances of 0·0005in. in the first two cases and 0·002in. in the last. In a general way a tolerance of 0·0005in. is not very alarming to even the general engineer, but when this is called for on, say, a 6-in. diameter, and has further to compare strictly with national standards, the difficulties of manufacturing are increased. Actually, instead of a tolerance of 0·0005in. as stated, only approximately a tolerance of 0·0003in. can be allowed with safety in the works, and this has to cover errors in parallelism and sphericity, as well as errors in diameter and changes in dimensions which occur whilst the work is in progress (sometimes many weeks) due to want of stability in the structure of the steel.

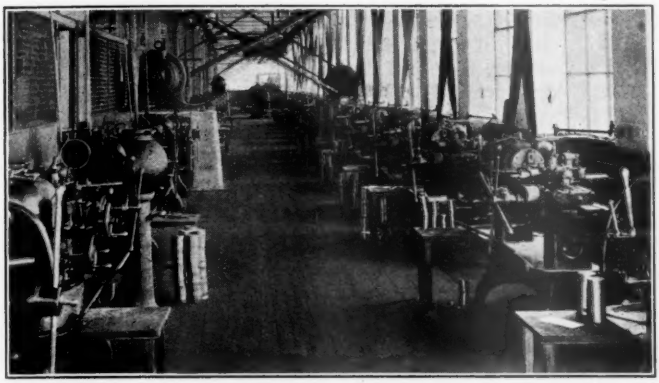
With regard to those dimensions which do not directly concern the user, such as diameter of ball track, track clearance, etc., an even greater degree of accuracy is called for; 0·00011in. is the unit used in the comparison of the race diameters, and



Drilling race blanks.

the balls employed in individual bearings are graded to 0·00002in. The finish on both balls and race tracks is the best that special facilities and years of experience can produce, and the state of perfection reached in this direction is somewhat

startling to the general run of visitors who inspect these products in course of production. Extreme care has necessarily to be taken with work in progress on account of the danger of the fine finish being destroyed by tarnishing. Weeks often



A portion of the machine shop.

A section of the inspection department.

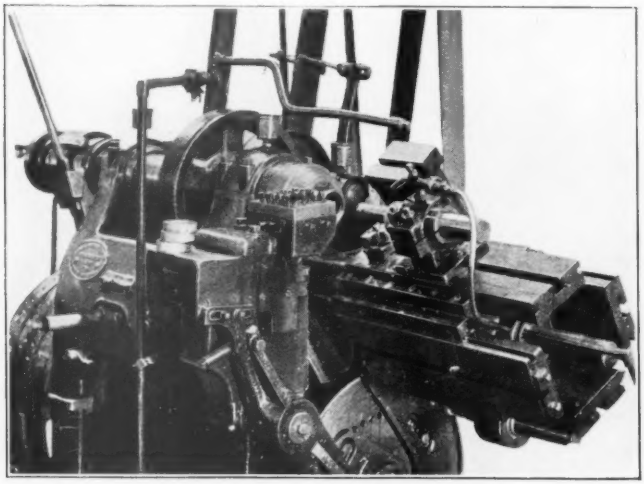
elapse between the components being finish machined and the packing operation, and in the meantime the finished surfaces must be covered with specially prepared greases to minimise any risk of stains.

Manufacturing departments and stores are maintained at a

temperature of 62° F., *plus* or *minus* 5° F. to reduce the alterations in dimensions to a minimum, and the humidity is maintained as low as possible further to reduce the risk of tarnish.

Reference gauges of both the inch and metric systems are compared periodically with the national standards of the N.P.L. at the standard temperature of 62° F. Metric gauges made by the Johannson Co. of Sweden are standardised at 20° C. (68° F.), and an assumed co-efficient of 0·000011in. per 1° C. is used to "correct" the lengths.

The internal organisation necessary to handle such a seemingly simple product as a bearing is actually fairly complicated and will be fully dealt with at a later stage.



Machining outer rings from tubing.

Materials.

Naturally the question of materials is one of primary importance, and generally speaking the present practice is to manufacture races and balls from high carbon chrome steel, though case-hardening steel is still used to some extent for this purpose.

The progress made during recent years in alloy steel manufacture has practically rendered the case-hardened ball-bearing obsolete.

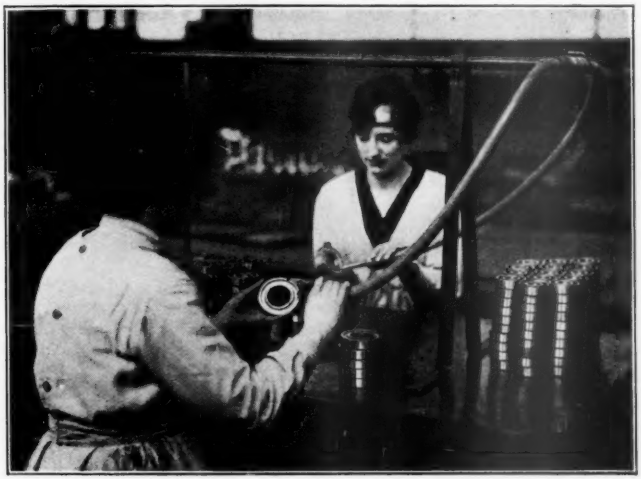
It is not contended by the writer that the carbon chrome steel race is greatly superior to the case-hardened one, if the latter is correctly heat treated, but no doubt the comparative simplicity of the hardening process for the direct hardening of steel is

responsible for the much greater regularity and reliability of product.

In certain cases, however, where the shock load might destroy the bearing, and where complete fracture might have serious consequences, it is preferable to employ case-hardening steel.

Chemical and physical specifications are given to cover carbon chrome and case-hardened bearings of standard design; also, case-hardening specification for bearings subject to shock loads, such as engine crankpins, etc.

The chemical specification for balls is similar to that of races, except that for sizes below ½in. the chromium content is a



Cleaning races by the use of compressed air.

gradually reducing quantity; thus for ⅛-in. balls this would be 0·25 per cent.

On receipt of the material, chemical and physical tests are carried out, and if the specification conditions are fulfilled it is stored ready for use. In the case of steel bars, a variety of colours is used to denote the steel manufacturer and the class of steel.

Hydraulically extruded brass tube and bars of high quality are used for the manufacture of cages, and a very high degree of ductility is required in respect to this material.

Before commencing a description of the manufacturing operations, it should be pointed out that bearings are made by the firm with which the writer is associated from the solid

R. & M. SPECIFICATION NO. 1 CHROME BEARING STEEL.

Chemical ...	Carbon	0·9 to 1·1%.
	Chromium ...	1·2 to 1·5%.
	Silicon	0·1 to 0·25%.
	Manganese ...	Not more than 0·5%.
	Nickel	,, ,, 0·5%.
	Sulphur	,, ,, 0·05%.
	Phosphorus ...	,, ,, 0·05%.
Physical ...	To be supplied annealed. Brinell impression not less than 4·1 mm. dia. on any surface or section with 10 mm. ball at 3,000 kg. load.	
Process ...	Open Hearth Steel.	

DIMENSIONS.

Nominal Diameter of Bearing.	Black Bar. Dimensions over Nominal Diameter.		Rough Turned Bar. Grinding Allowance.	
	Low.	High.	Low.	High.
Up to 2¼ in.	0·08	0·12	—	—
Over 2¼ in. and up to 3 in. ...	5/16 in.	5/16 in.	0·04	0·06
,, 3 in. ,, ,, 4½ in. ...	¼ in.	3/8 in.	0·058	0·081
,, 4½ in. ,, ,, 6 in. ...	5/16 in.	7/16 in.	0·058	0·081
,, 6 in. ,, ,, 8 in. ...	7/16 in.	5/8 in.	0·082	0·117
,, 8 in. and upwards ...	5/8 in.	13/16 in.	0·100	0·140

Rough turned bars to be centred to suit 75° angle centre.

Freedom from defects.—Bars to be straight and free from laps, cracks, flaws, and must machine clean on nominal diameter.

Length of Bars.—4ft. 6 in. to 5 ft. 6 in.

TUBES.

8 ft. to 10 ft. long.

Turning Allowances.	*Outside Diameter* ...	Plus 1·75 mm. to 2·25 mm.
	Inside Diameter ...	Less 25% of wall thickness and 2½ mm. provided that the total does not exceed 4½ mm.

These limits must be strictly adhered to, particularly as regards the outside diameter.

bar or tubes, according to the size of bearing and the quantity required. Sizes up to 2 5/16 in. O.D. and over 5in. are invariably made from bar, whilst those between are made from tube, and both methods of production will be fully described.

As regards the comparative merits of tube and bar, both from the point of view of cost of manufacture and of the quality of the product, there is no doubt as to the superiority of the tube. The nature of the fractures and the resilience of the rings made from tubes cannot be equalled by rings made from bar. This is, of course, what one might expect on account of the extra amount of work put into the steel, and because

R. & M. SPECIFICATION NO. 4 CASE-HARDENING MILD STEEL.

Chemical ...	Carbon ...	... 0·15 to 0·2%.
	Silicon ...	... Not more than 0·15%.
	Manganese	... 0·6 to 0·95%.
	Sulphur ...	... Not more than 0·05%.
	Phosphorus	... ,, , 0·05%.
Physical ...	Brinell impression not less than 4·6 mm. on any surface or section with 10 mm. ball at 3,000 kg.	
Process ...	Open Hearth Steel.	

DIMENSIONS.

Nominal Diameter of Bearing.	Black Bar.		Rough Turned Bar.	
	Dimensions over Nominal Diameter.		Grinding Allowance.	
	Low.	High.	Low.	High.
	in. mm.	in. mm.		
Up to 2¼ in. (56 mm.) ...	0·08 (2·0)	0·12 (3·0)	—	—
Over 2¼ in. (56 mm.) to 3 in. (76 mm.) ...	¼ (6·5)	⅜ (9·5)	0·04	0·06
,, 3 in. (76 mm.) to 4½ in (114 mm.) ...	⅜ (9·5)	½ (12·5)	0·058	0·081
,, 4½ in. (114 mm.) to 6 in. (152 mm.) ...	½ (12·5)	⅝ (16·0)	0·058	0·081
,, 6 in. (152 mm.) ...	¾ (19·0)	1 (25·0)	0·082	0·117

Rough turned bars to be centred to suit 75° angle centre.

Freedom from defects.—Bars to be straight and free from cracks, laps, flaws, and must machine clean on nominal diameter.

the billet must of necessity be sound to permit of it being worked up into a concentric tube.

Manufacturing Methods.

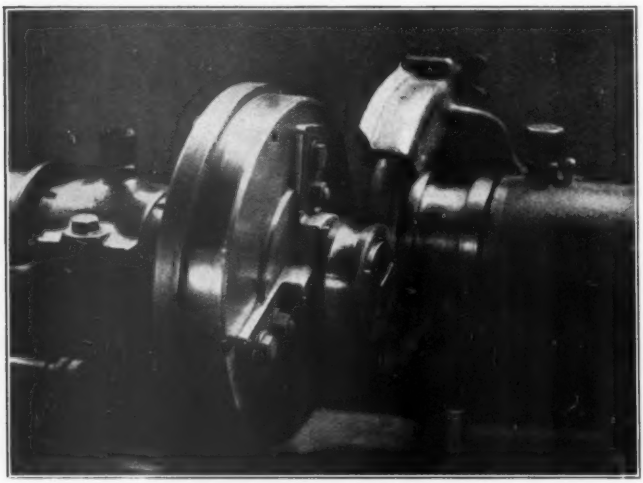
Solid Bars.—Solid bars are ordered rough turned (leaving a light cut to be removed) in order to give the steel manufacturer an opportunity to examine the material before despatch. The bar is machined over its entire length in a lathe using a roller steady, and no further machining is done on this diameter until after hardening.

Turning.—The roller steady shown was designed and made by Messrs. Ransome and Marles, and is probably of interest to other than ball bearing manufacturers. In a length of 6ft. and upwards a bar of 8in. diameter can be turned to within a tolerance of 2,000ths of an inch at one cut. Previous to this roller steady being designed a grinding operation was necessary, but has been eliminated by the use of this attachment.

After the turning operations the bars are examined for diameter.

Parting Down.—Next, the bars are parted down with double parting tools using tool blanks of inferior cast steel with high-speed tips welded on. "Stellite" is used for tipping for most other turning operations, but no success has been obtained with "Stellite" tipped parting tools as yet.

Drilling.—After being tested for width, the centres of the blanks are removed by trepanning if the core is worth saving. Otherwise they are drilled in machines specially designed for the purpose, a feature of these tools being the power bar-raising device.



Grinding tracks in inner rings.

Facing Blanks.—Facing the sides of the blanks follows trepanning, and for this operation a simple lathe with an automatic cross traverse is employed. "Stellite" tipped tools are used, and the work rotates at a speed of 180ft. per min.

Stamping.—After inspection for width the blanks are stamped with the firm's trade mark, the type and size of bearing, and a symbol indicating the quality of steel used, the month and year of its manufacture, and the maker of the steel. For instance, H_2D_2 signifies a chrome steel bearing made in April, 1920, from Brown Bayley's steel. The same symbol is impressed on the blanks in two places to suit the position of the inner and outer after trepanning.

Trepanning Races.—The next operation is to separate the

R. & M. SPECIFICATION NO. 5 CASE-HARDENING MILD STEEL FOR BALL AND ROLLER BEARINGS.

Chemical ...	Carbon	0·28 to 0·35%.
	Silicon	Not more than 0·15%.
	Manganese ...	0·4 to 0·6%.
	Sulphur	Not more than 0·05%.
	Phosphorus ...	„ „ 0·05%.
Physical ...	Brinell impression not less than 4·6 mm. on any surface or section with 10 mm. ball at 3,000 kg.	
Process ...	Open Hearth Steel.	

DIMENSIONS.

Nominal Diameter of Bearing.	Black Bar.		Rough Turned Bar.	
	Dimensions over Nominal Diameter.		Grinding Allowance.	
	Low.	High.	Low.	High.
	in. mm.	in. mm.		
Up to 2¼ in. (56 mm.) ...	0·08 (2·0)	0·12 (3·0)	—	—
Over 2¼ in. (56 mm.) to 3 in. (76 mm.) ...	¼ (6·5)	⅜ (9·5)	0·04	0·06
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„ 6 in. (152 mm.) ...	¾ (19·0)	1 (25·0)	0·082	0·117

Rough turned bars to be centred to suit 75° angle centre.

Freedom from defects.—Bars to be straight and free from cracks, laps, flaws and must machine clean on nominal diameter.

blanks and at the same time perform a few minor operations. The shaft hole is bored to a tolerance of 0·004in., leaving approximately 0·006in. to 0·01in. in the bore for grinding, and the standard radius turned. Trepanning comes next, cutting half way through from each side, and whilst the outer ring is still in the chuck the inside diameter is bored to size.

Slide.—Proceeding now with the outer ring, the edges are chamfered inside and radiused on the outside. The radius tool is of circular formation, and is ground on the face only.

In the case of a standard roller bearing the turning operations on the outer ring are now complete, but for a ball bearing the ball track requires forming.

Subsequently the turning operations are checked in the inspection department.

Tracking.—A somewhat novel method has been devised to gauge the tracks during machining. A Starrett indicator is secured to the tool holder, and the shoe arranged in contact with the top diameter of the chuck (previously turned true to receive

it), and the position of the pointer noted from a ring of known size. This method has been found to be much more reliable than the employment of stops, as the spring of the tool has to be taken into account.

Milling Notch.—The ball insertion notch is end milled in a small hand-milling machine by means of a special jig which locates from the tracks.

Tracking Inner Ring.—Reverting to the operations on the inner ring, this is next gripped on an expanding collet in a No. 4 Herbert capstan and turned on top, tracked, and chamfered; next, the ball notch is machined as previously described.

Securing cage rivets.

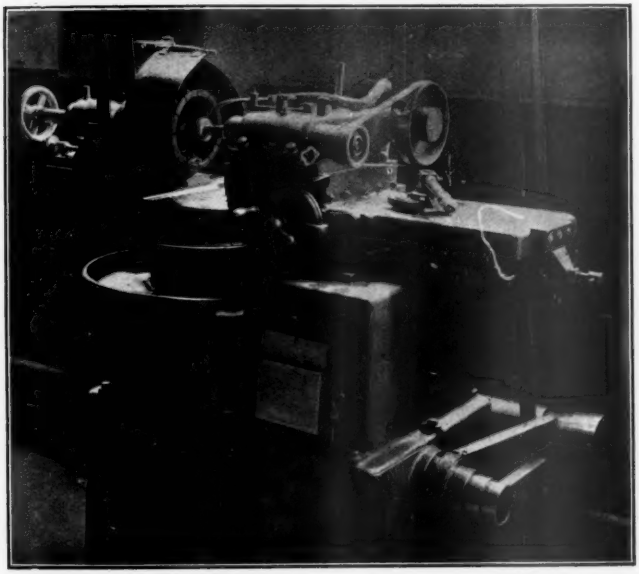
The foregoing outlines the general method of turning bearings from bar, but modifications are made in some cases. For instance, in very large bearings, where the gap between the rings is wide, the rings are machined from separate bars to avoid excessive waste of material.

Tubes.

Turning Tubes.—The alternative method of machining rings from tubes is now generally employed by Messrs. Ransome and Marles. An illustration shows a tube being machined in a

single-spindle automatic machine which is of the usual type used for this purpose.

The primary operation is to rough turn and bore to a sufficient depth for four or five rings, and then to part off that number with the aid of multiple parting tools. No radiusing is attempted at this setting, because the increased time necessary to set up is not compensated for by the time gained on the quantities handled. The inner races are made either from tubes or bar according to the relative cost of material and labour.



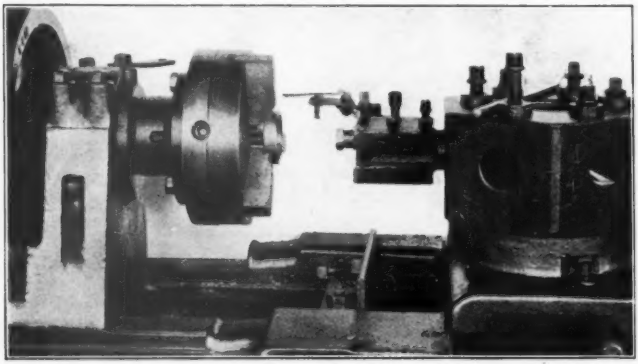
Grinding tracks in outer rings.

Radiusing, chamfering, and notching are carried out precisely as outlined for rings made from solid bars.

Stamping is done singly, and not in duplicate as for solid blanks.

Bearings up to $2\frac{5}{16}$in. outside are machined on four-spindle Gridley automatics, and the sequence of operations is as follows :—

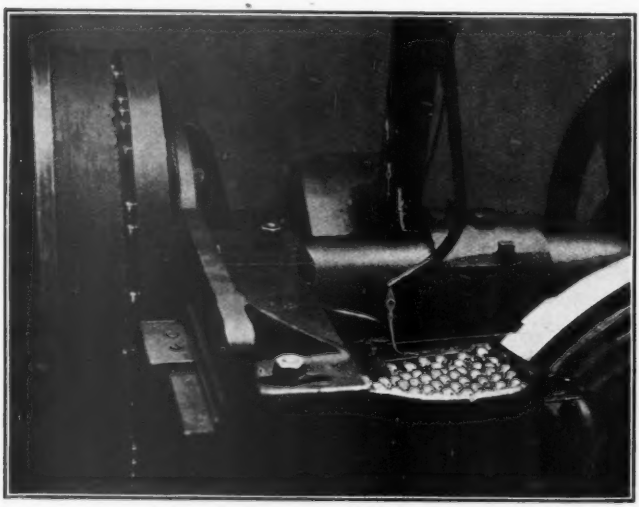
1. Turn, drill, face front, and part down.
2. Trepan and bore (outer comes away).
3. Turn and track inner.
4. Cut off inner ring.



Arrangement of indicating device for track forming operation.

Hardening Operations.

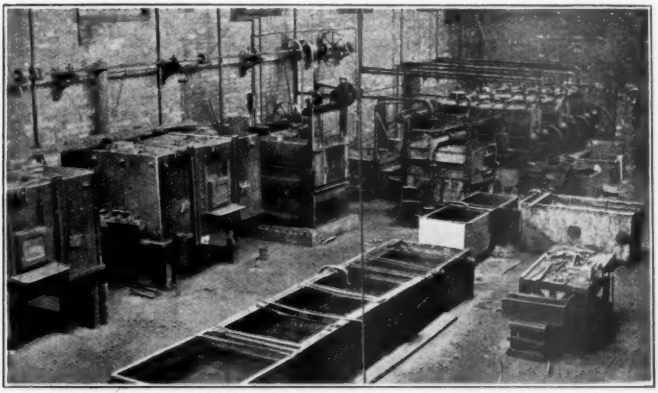
Hardening.—The next group of operations is carried out in the hardening department, of which a view is shown. To the left may be seen two special furnaces designed some years ago by Messrs. Hoffmann, and two Revergen furnaces, designed and made by Messrs. Davis, of Luton. In the background may



Ball grinding machine.

be seen the revolving ball hardening furnaces, to which attention will be drawn later, and in the foreground the water and oil tanks for quenching. To the right of these tanks may be seen the covers of the oil cooling tank, which is simply a network of pipes submerged in a tank of running water. At Newark the water supply is so plentiful that no special arrangements for cooling the water are necessary.

All furnaces are fitted with suitable temperature-recording instruments, which undergo periodical checks against a standard instrument made by the Cambridge Scientific Instrument Co., and it may be noted this firm's instruments are used exclusively in the hardening department. The usual hardening tempera-



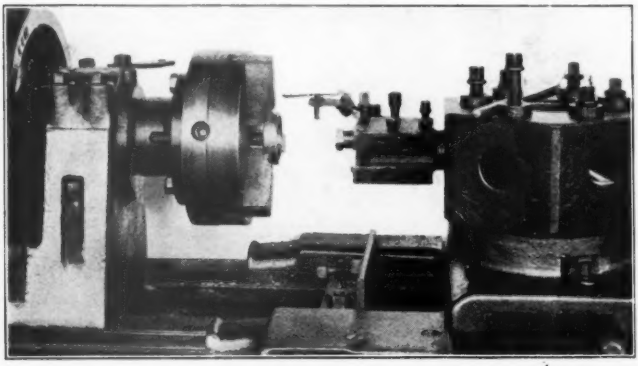
General view in hardening shop.

ture for carbon chrome steel is from 780° C. to 820° C. according to the size of the ring. Quenching is done in oil, which is kept at approximately 65° F.; after hardening, the rings are tempered in oil at a temperature approximating 170° C. according to the area of the section.

Rings scrapped in the turning operations are used as test rings for the hardening process, and the fractures are systematically examined by experienced metallurgists.

After tempering, all rings are subjected to a drop test for resilience, the height being determined by the weight and section. This drop test is a certain indication of brittleness or faulty hardening; if too hard the ring will crack, and defects in structure are obvious to the trained ear of the inspector.

Following the resilience test, races are examined for superficial hardness by means of a bastard cut file.



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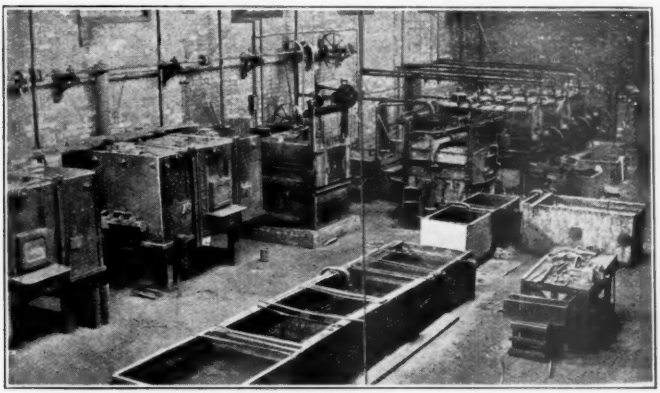

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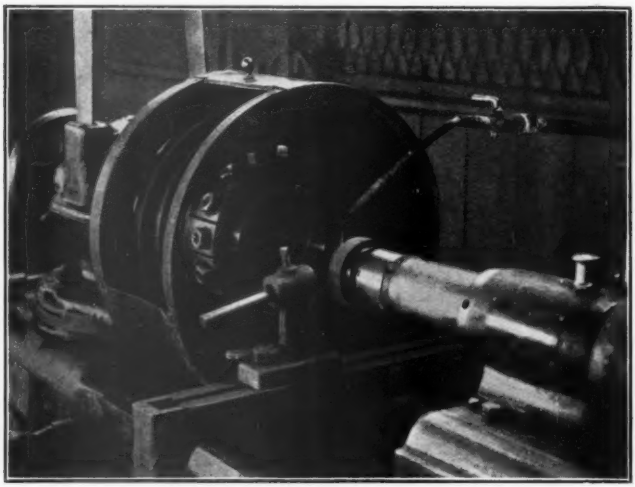
Case-hardening is carried out in the two Richmond furnaces shown, the rings being packed in a standard casing mixture and raised to, and maintained at, 900° C. for a period determined by their size and the depth of the case required. This case is much deeper than is customary for ordinary machine parts.

After cooling, the rings are raised to 900° C. and quenched in water. They are then raised to 760° C. and again quenched.

The hardening of carburised rings is carried out on a special fixture in order to prevent distortion. Fractures are obtained and examined in the same way as for chrome steel rings, and



Details of ring holding chuck.

occasional analyses are made of carbon content at varying depths.

A minimum depth of casing is called for on case-hardened rings according to the cross-sectional area, and this is checked by means of a special machine, in which a weighted ball is dropped from previously determined heights as being sufficient to enable the ball to break down a case which is less than the minimum thickness.

All hardened work is examined as regards the grinding allowances to constitute a check on hardening distortion before finally passing to the grinding department.

Grinding.

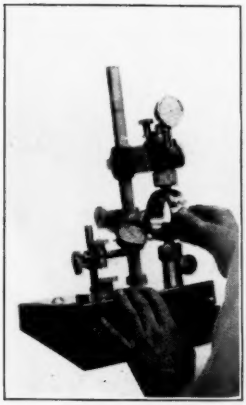
In this section is commenced a series of operations where low production costs are combined with the highest class of

workmanship, where so-called semi-skilled labour carries out work of the closest accuracy.

Sub-division of duties is necessarily well developed, and this accounts for the deftness and precision achieved. Scientific organisation and equipment design are factors which have been developed to the fullest extent to decrease the element commonly known as the "human factor," and to reduce both the handling time and the actual times of operations.

Facing.—Operation No. 1 on standard ball bearings consists of facing both sides of rings (inners and outers) on Blanchard grinding machines, where the work is held down by magnetism on a large revolving table, and the top face ground by a grinding wheel of hollow cylindrical form which removes the necessary amount from one face.

Previously, in the turning department, the rings are located against one particular face—the stamped side—and conse-



Inspection test for depth and concentricity of track, etc.

Gauging outside diameter of outer ring.

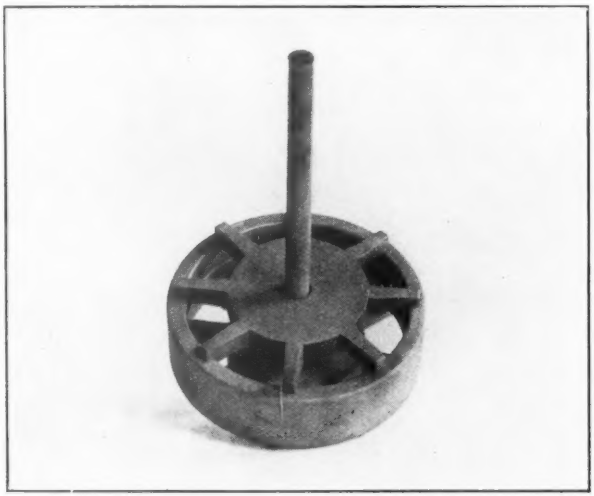
quently, on account of the wider tolerance given in the turning department, the amount removed in the first facing varies, but the track is more nearly central than if the rings had been "spotted" from either face in turning. This procedure is necessary also to preserve a regularity in depth of the stamped symbols.

After first facing, the rings are turned over and faced to the standard tolerance, 0·002in., but a parallelism of approximately 0·0005in. is required, this figure varying slightly with the diameter of the ring.

Various types of grinding wheels have been tried for this work, and a special elastic wheel has proved to be very efficient. An analysis of the sludge accumulated in the base of the machine shows over 99 per cent. of iron in its composition, and the sponge-like substance resembles an average pile of steel turnings under the microscope.

Since the above notes were written a sample wheel of American manufacture has given even better results than the elastic wheel at present in use.

After grinding the faces a modified Brinell hardness is imposed, a 5mm. ball being used. The impression is not measured except comparatively by the trained eye of the in-



Plates for quenching carburised rings.

spector. This test is not absolute, but is used principally as a warning, the attention of the process inspection official being drawn to work which is suspected of softness.

Examination of the facing for dimensions and parallelism follows this operation—a test of quite a simple character. A clock indicator is used, and the work turned underneath the anvil.

Grinding Outside Diameters.—Tolerances: English sizes, 0·0005in., all sizes; metric sizes, up to 50mm. to 0·013mm., over 50mm. to 0·020mm.

The method generally adopted is to mount a number of these on a mandrel between a fixed collar and washer, the necessary

friction being obtained by means of a fine-threaded nut. The rings fit loosely on the mandrel, a preliminary light cut over the top serving to show where the rings are out of truth. They are tapped sufficiently true for grinding by means of a small hammer, and the nut is not finally tightened until the truing process has been performed.

Nothing better was known for this operation until the special mandrel now being used by Messrs. Ransome and Marles was invented and patented. In the use of this mandrel several important improvements over the old method are obtained. Previously, in the case of a light ring, it was difficult to avoid distortion of the ring when tapping true. With the new method the rings are automatically set true in relation to the track on its internal diameter.

This feature is of great assistance in carrying out the follow-

A typical selection of special gauging apparatus.

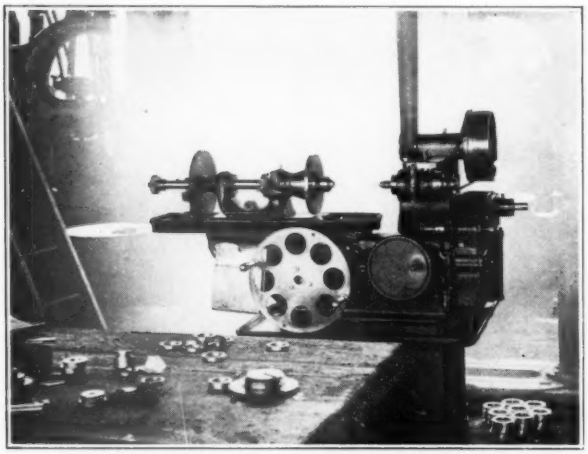
ing operation, as the grinding allowance is cut down to a minimum. All that was previously required was that the rings should be ground to the tolerances stated, and that the top diameter should be ground all over; consequently the section between the top diameter and the rough ball track could vary to the extent of the eccentricity tolerance in the turning department, plus the grinding allowance on top, if this was not removed equally from the surface.

Description of the Mandrel in Use.—The mandrel is mounted upright with the square end fitting in an iron plate secured to a bench close to the grinding machine, and the outer rings are taken one at a time and a ball cage slipped into position. Next, the ring and cage are placed on the mandrel, and a taper sleeve,

pressed into position by hand, expands the balls into the rough track and thus centralises the rings.

This operation is performed on a standard plain grinder, and a simple gap gauge is used to determine the finished size. In conjunction with this gauge a disc of mean diameter is used as a constant reference, an ordinary micrometer being employed to determine the amount to be removed.

Successful experiments have been carried out with a dial indicator gauge of special type, reading directly from the work, but the advantage gained was not considered sufficient to warrant general installation.



High speed ball bearing drilling machine for rivet holes in cages.

The checking of the diameter follows, and the rings are revolved by hand under the anvil of minimeters.

Grinding Race Tracks.—This operation is carried out on a machine made in the smaller sizes by the Van Norman Machine Co., U.S.A., and in the larger sizes from a special design prepared by Messrs. Ransome and Marles, of Newark-on-Trent. In both cases the inherent principle is the same, viz., the work head oscillates about an axis which passes through the centre of the circle forming the ball track. Several modifications have been embodied in the later machines to facilitate production and improve the product.

One of these improvements consists of a wheel forming and truing attachment mounted on Ransome and Marles ball races. With this arrangement the necessary freedom of rotation, com-

bined with an entire absence of slackness, is obtained. The ordinary type consists of a plain pin fitting in a plain hole, which, no matter how good a fit, fails to give a suitable condition of wheel surface.

Chucking Outer Rings.—A further modification, or perhaps addition, in this case is the method of gripping the ring for grinding. A tolerance of 0·0005in. eccentricity is given, and,

Visual inspection of balls.

until the device now in use was invented and patented, working to this tolerance was found to be particularly difficult, and the scrap and rectification percentages were exceedingly high. However, the introduction of the present method of chucking has removed one of the chief causes of trouble met with in the manufacture of ball and roller bearings, and rings can be re-chucked in a few seconds sufficiently true to permit a cut of 0·0001in. to be removed concentrically from the ball track.

Considering the fact that the tolerance on the outer diameter is 0·0005in., and that work with this variation has to be handled without selective assembly, the difficulties to be met with when using standard equipment will be readily realised.

As far as the writer is aware, in all other similar work where the same close limit of eccentricity is required the rings have to be placed in position in fixed jaws by force, and the process of extraction, with the consequent rapid wear on the locating pieces, is the cause of considerable scrap and rectification. As a comparison it may be noted that a tolerance of 0·0002in. eccentricity could be readily obtained by the improved method.

The rough grinding of the ball tracks is performed by a

Ball inserting device.

46K wheel running at a speed of 4,000 to 5,000ft. per min. Approximately 0·002in. is left on for the finishing operation, which is carried out with a special elastic wheel operating at a speed of 3,000 to 4,000ft. per min.

Soda water is used as a lubricant for the roughing operation, and machine oil applied with a piece of thin stick is found necessary for finishing. Beeswax is occasionally applied to the wheel to remove any trace of sharpness. It may be remarked that very little material is removed in this final grinding operation.

Gauging of Track Diameter by Operator.—The tolerance on track diameters for the standard product is ±0·002in., and the gauging is performed as follows: A cage of balls is inserted inside the ring to be measured, and a plug having a taper of 0·010in. per in. is inserted into the cage.

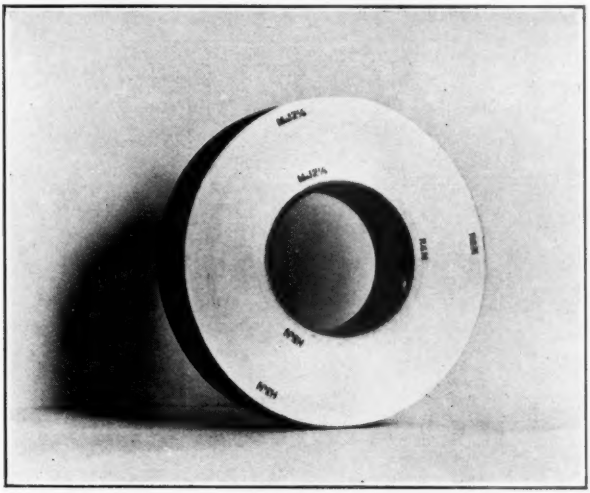
Following the grinding of the ball tracks, examination of the following features takes place:—

1. Track position in centre of width.
2. Track parallel with sides.
3. Roundness of track.

} In one fixture.

4. Formation of track.
5. Concentricity with outside diameter.
6. Finish of track.

Grinding of the Notch in Standard Outer Rings.—Several attempts have been made in the writer's own experience with machines for performing this operation, but the best and



Showing stamping of symbols before trepanning (bar method).

quickest work is produced by expert operators holding the work in the hands and using a suitable wheel carried on a ball-bearing spindle. As the wheel is in contact with the work through a wide angle, there is a tendency to overheating, and, this being immediately detected by the hand, the danger is removed. The notch having been milled at an angle of approximately 5° clearance, the operator readily follows this angle for the small amount to be removed. An examination of rings for height of notch above track follows this operation.

Standard Inner Races (Facing).—This operation is generally carried out along with standard outer rings, being of the same width and of the same degree of accuracy.

Examination for width and parallelism follows this operation,

as well as a hardness test performed by means of a modified Brinell impression method.

Grinding Shaft Hole (Boring).—The rings are roughly set by hand in special chucks which hold them lightly by means of spring tension, the jaws bearing on the front face. The wheel is brought to bear against the side of the hole, and the pressure quickly centralises the ring. A knurled knob at the rear of the spindle is gripped while the spintlle is rotating, and the work is thus tightly secured for grinding. A few seconds only are necessary to perform the entire setting and gripping motion. By means of this apparatus, designed and made by Messrs. Ransome and Marles, the grinding allowances are reduced to a minimum.

Fixture for determining radial freedom between races.

To facilitate the truing of the wheel, which must be done to finish each hole, a quick setting diamond holder is attached to each machine, and this fitting can be swung in and out of position instantly.

The trial gauging for size is done by means of a taper plug tapering 0·010in. per in. and carrying a mark which indicates the full nominal size. This is found to be the most convenient means of indicating to the operator the amount of material to remove, and also provides a convenient way of checking the hole for taper. The hole is finally checked by means of a parallel plug gauge.

Examination for size, parallelism, and roundness of the bore follows this operation, and special fixtures are employed.

At this point attention might be drawn to the ball-bearing

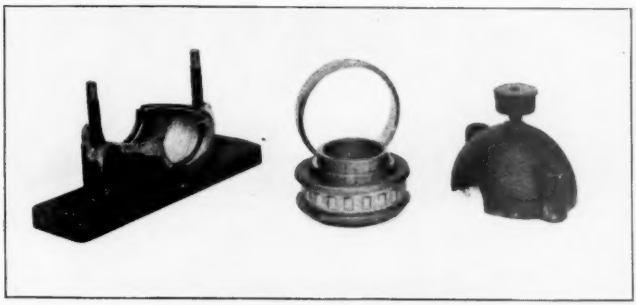
spindle employed in the grinding machine. Designed and made at Ransome and Marles's works, this spindle runs for months on end at speeds varying from 16,000 to 30,000 r.p.m. without any adjustment, and for the purpose is by far the best spindle that has been discovered.

This and other high-speed ball bearing spindles rely for their success on excellence of workmanship and design.

Track Grinding Inner Race (Ball Journals).—This operation differs from the similar operation on the outer ring in that the formation of the track depends entirely on the form of the wheel, as the work head does not oscillate round the centre of the track circle as is the case in the outer ring tracking machine.

The same wheel is used on both roughing and finishing operations. In this operation, to a greater extent than in the corresponding operation on the outer ring, the necessity for the ball-bearing diamond truing device is demonstrated.

Absolute rigidity, combined with smoothness, are necessary



A roller bearing plummer block.

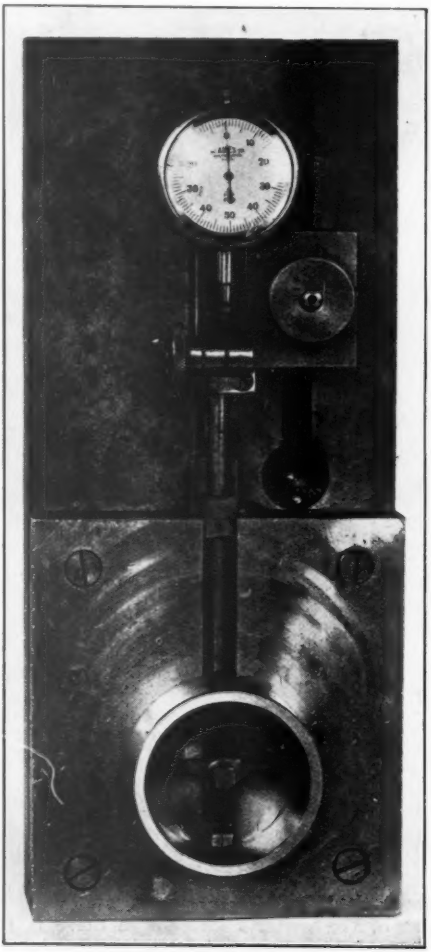
in the swivelling action, and these can only be secured by such an accessory.

The deciding test for hardness, and certainly the most reliable, is the scraper test. The scraper is made from a piece of silver steel of maximum hardness and ground square by its axis. Its proper use demands considerable experience, and can only be employed effectively by a trained viewer. Very little more than the weight of the scraper is applied and at the correct angle. This apparently crude method gives very effective results, but the fact that expertness is required is its principal drawback.

To the best of the writer's knowledge there is no practical method of determining the correct hardness of hardened steel, if the class of labour which can handle, say, a Brinell machine for unhardened steel is employed.

Judging from recently published papers on the subject, scientific minds are endeavouring to solve the problem, but so far nothing of use to the ball bearing manufacturer has been evolved.

Grinding Ball Insertion Notch.—The method employed for



Special gauging device for diameter and concentricity.

performing this operation is precisely the same as that used for the corresponding operation on the outer ring.

Grinding Operations on Magneto Bearings.—Of the bearings made for special purposes the magneto bearing M15 might be selected for special consideration on account of the difficulties which arise in meeting the specifications. These bearings are probably the most difficult ball bearings to manufacture when the selling price is borne in mind. The faces are ground in the same manner as other bearings, tolerance, ±0·03mm.; outside diameters are ground on special mandrels which position the internal track true, the tolerance being ±0·01mm.

Next the ball tracks are ground and lapped, tolerance on track diameter, ±0·006mm.; tolerance on position of track in relation to side, ±0·015mm.; ball clearance, 5 per cent. to

Die cast roller cages.

disc gauge. A secondary radius is ground to leave the point where the two radii intersect 0·006mm. thousandths less than the track diameter, the tolerance being ±0·006mm. on this diameter.

The shaft holes are ground in precisely as other inner rings are ground; tolerance, $^{+\ 0{\cdot}000}_{-\ 0{\cdot}001}$mm. Tracks are ground and lapped as other rings are ground; tolerance, 0·006mm. on diameter and ±0·015mm. on position of track with sides.

These bearings have all their inner and outer rings absolutely interchangeable within the specified tolerances on assembled bearings.

Selective Assembly System (Ball Journals).

The system of "pairing-up," as this operation is called in the works, consists of selecting outer and inner rings of corresponding size for assembly, instead of grinding the inner

ring to suit the outer individually, as is the general practice in ball-bearing manufacture.

This system has been developed as a result of much careful study, experiment and experience, the primary object being to avoid the danger of fine grit being rolled into the track during the "cut and try" method of fitting the races. It is found that unless the utmost care is taken, the presence of this fine

Gauging for thickness and parallelism.

grit can be felt in the running of the bearing, and microscopic examination reveals its presence in the tracks.

A further object was increased production, and it might be mentioned that from two to three times the number of tracks can be ground with this system than with the individual fitting method. This is on account of the comparatively large tolerance given (0·001in.) on the inner track diameter.

After the inner tracks are examined for track formation, finish, etc., they are checked for diametric tolerance to specifi-

cations issued by the "pairing-up" department. The rings then pass to this section for graduation and trial assembly.

Subsequently the pairs of rings proceed to the final inspection department. Rings which are rejected for any fault are re-tracked (the outer rings to the next larger range), and the same procedure is carried out. In the case of faulty inner rings, these are stored until a sufficiently large batch is accumulated, when a special batch of outer rings is tracked and the faulty inners re-tracked to suit.

Ball bearings are paired up in three classes of fit—X, Y and Z.

Bearings of the first class are seldom recommended, but some users insist on having no perceptible "side-play," and these must therefore be made. Y fits are recommended for general use, the slight perceptible "side-play" representing no more than a few tenths of a thousandth of an inch diametric clearance, and serving to accommodate a small contraction of the outer ring and expansion of the inner ring during assembly, and also to accommodate the bearing to small errors of alignment; Z fits are intended for electrical motors, etc., where the inner ring may be subjected to heat from the shaft and also for excessive errors of alignment on a springy housing.

Diametric clearance between the races is measured practically by the relationship of the amount of sideways movement of the inner in the outer race to the amount of difference between the two race diameters, less the size of balls. The magnified movement makes the operation simpler and more accurate.

Generally speaking, the same procedure is carried out with roller bearings.

Roller Bearings.

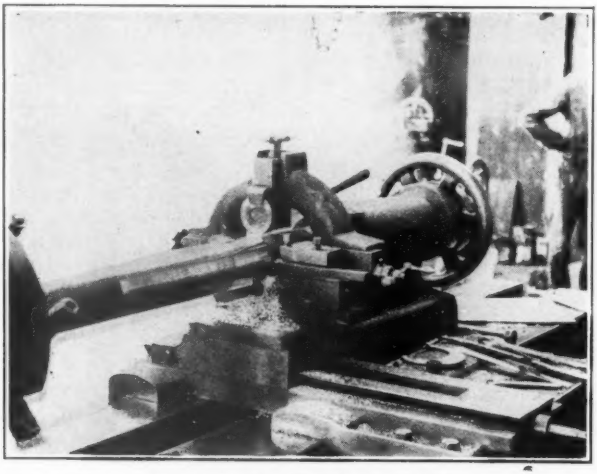
Regarding roller bearing manufacture, very little by way of description is required. No lapping or polishing is permitted of Ransome and Marles roller bearing tracks, and the standard of workmanship and finish is very high.

The writer is not aware of any other engineering product which demands such high-grade workmanship as ball or roller bearing tracks. Parallelism is required to be within 0·00005in. to avoid a tendency to move endwise.

On the question of track finish there is a considerable difference between the methods adopted by the various bearing manufacturers. The most common practice is to grind the track once and follow with a good scouring with No. 3 emery cloth, and there is every reason to assume that the majority of ball bearings used are made in this way; in fact, this method is also adopted to control the fit of races. In other words, the rings are ground so that, with the balls in position, they are tight,

and the easing process is carried out by means of coarse emery cloth. This method might be styled the "Continental method," and is not generally carried out in this country, for obvious reasons.

In general, the requirements of the engineering industry of this country, particularly in the case of the automobile industry, call for bearings of quieter and smoother running properties than can be made by this method, and the procedure adopted by the firm with which the writer is associated is to attempt to grind all race tracks so that no lapping is necessary. Where



Rough turning bars (bar method).

polishing is necessary it is only of a trivial character, and no perceptible material is removed.

Journal Cages.

Brass journal cages are made from extruded tube or bar as convenient. When tube is used, sufficient material, usually about 2mm. on the outside and 3mm. inside, is allowed for machining. Single spindle Gridley automatics are used exclusively for the turning operations.

A length sufficient for four to six rings (in this case two rings are required for one cage) is fed up to the stop. Inside and outside diameters are then machined, and the rings are parted off.

At a second operation the hole is bored and the edge of the ring which is to the outside of the bearing is chamfered.

At the next operation the rings are mounted in pairs on the

spigot of a special drilling machine and the rivet holes drilled. This machine is of the firm's own design and manufacture, and deals very effectively with the small diameter holes. The drill spindles have been converted from ball-bearing grinding spindles with great success. Incidentally it might be mentioned that experience has taught what can be done with a small drill running in a true well-fitting spindle, and that looseness even in the slightest degree is a cause of innumerable broken drills.

Two rivets are pushed into opposite rivet holes, and the operation of drilling the ball seats is proceeded with. Here also the firm have had to rely on machines of their own design.

Die Cast Cages.

The firm's patent roller bushes are die cast from high quality bearing metal, Findlay's L.1 being used for preference.

An illustration shows some types of the roller bush employed,

A typical selection of R. & M. ball and roller bearings.

and certain parts of the mould are also to be seen in this view. It may be noted that reinforcing wire is cast into the rim of the cage.

The rollers are eased by pressure being exerted on the outside and inside against the seating of the rollers.

This roller bush has found innumerable users where high load carrying capacity is required and space is limited; they are used exclusively in the Ransome and Marles self-aligning plummer blocks.

Final Examination.

Components are passed through the final inspection department on their way to the assembly section. Examination is carried out for dimensions, form of track, surface material defects, finish, hardness, and relative track diameters of inner and outer rings.

Most of those features cannot, of course, be examined when the bearing is assembled.

Passing from the final inspection department, the components are fitted with balls and cages. The majority of the complement of balls required for a bearing can be assembled without straining the rings, but the remainder are inserted as shown in an accompanying illustration.

A double lever with cam-shaped ends is applied between the rings, one jaw on each side of the notch. On pressure being applied to the handles the rings are sprung slightly further apart and the ball previously suspended in the notch drops into the track.

The cages are next assembled and the rivets fitted, the heads of which are heated and formed in an electric riveter.

After assembly all bearings are freed from dust and grit by means of a high pressure air jet. Air at 40lb. per sq. in. is blown against the balls, the inner race being held in the hand, and the outer member allowed to revolve at a high rate of speed. Various washing methods have been tried, but nothing is found so effective as high-pressure air.

Following the assembly the complete bearing is subjected to a further examination for superficial dimensions (outside diameters and bores) and smoothness of running.

After successfully negotiating all tests the bearing arrives at the packing stage, and is filled with suitable grease, wrapped in paper and packed individually in boxes, which are marked with the type and size of bearing and its particular degree of side-play.

A final word regarding the grease is perhaps advisable. It would seem obvious that a good average lubricating grease free from grit would be quite satisfactory for bearings of the character described, but it cannot be too strongly emphasised to ball bearing users that the grease should be free from acid, alkali, and water, and unless it is obtained from a reliable maker with that guarantee the bearings are liable to rapid deterioration.

Ball Manufacture.

The methods used in the manufacture of balls have been fully described in the technical press, and a detailed description will not be attempted in this paper.

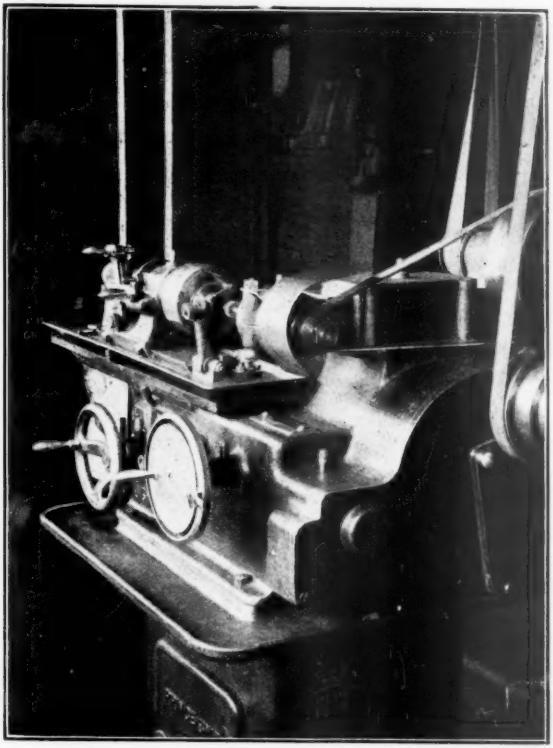
Briefly, no balls are turned by Ransome and Marles, all sizes being forged, sizes $\frac{1}{2}$in. diameter and over being hot forged from slugs previously cropped from the bar, whilst ball sizes below $\frac{1}{4}$in. diameter are cold forged automatically from coils of wire.

The advantage of the forged ball over the turned ball is its much greater resistance to crushing.

Rough Grinding and Lapping Machine.—The machine of

principal interest in ball manufacture is the lapping machine, on which the last operation on the balls previous to hardening is performed, roughly 0·005in. being left for lapping to size.

The same process is carried out three times with different grades of wheels and with different pressures. Although the



Grinding bores of inner rings.

finish obtained from the last lapping would be considered excellent for an average engineering job, several barrelling operations are subsequently carried out to give the requisite sparkling finish. The amount of material removed after lapping is approximately 0·00001in. With careful attention this machine will produce a batch of balls within a maximum variation of 0·00002in. in diameter and sphericity, and, considering the

inherent difficulties of manufacturing spheres to such a degree of accuracy, the extreme simplicity of the machine and its operation are probably unique.

In ascertaining the crushing load of balls, Messrs. Ransome and Marles have a different system from that generally adopted. The usual method is to use three balls of the same diameter encased in a loosely fitting tube, and to have the top and bottom balls seated in dies in the press; the middle ball, of course, is the one which first fails, and the crushing load of this ball is recorded. One of the chief objections to this method is that the varying hardness of the two end balls can, and does, affect the apparent crushing load of the middle ball to a considerable extent. The method used by the writer is to employ two hardened blocks of special die steel having flat faces, between which the ball is placed in the press. Using a different location for each test, a more accurate reading of the crushing load is obtained, as the conditions are as near as possible the same in each case.

Standard balls are made and sold under a guarantee of within *plus* or *minus* 0·00001in. of standard.

Balls used in Ransome and Marles bearings are further graded into batches varying by two hundredths of a thousandth of an inch (0·000002in.), and only balls of one grading are used in any particular bearing.

Works Organisation.

It will be appreciated that the methods already described, involving as they do a multitude of operations and corresponding inspections between the bearing in the state of raw material and finished product, call for a careful and comprehensive organisation, capable of efficiently controlling costs, delivery rates, methods of manufacture, and materials.

It may be explained that the responsibility of all the executives is to the works manager, their respective functions being as follows.

1. *Technical Manager.*—Responsible for the design of bearings and all applications, together with inspection methods and standards.

2. *Equipment Designer.*—Responsible for the design of all jigs and tools for routine work in the factory, and all special machines for production.

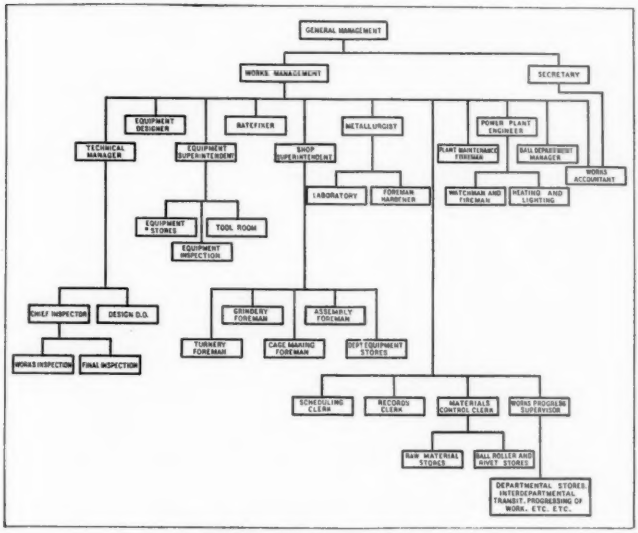
3. *Equipment Superintendent.*—In charge of the tool room and responsible for obtaining the necessary supply of equipment to designs of the equipment designer, and for keeping suitable and adequate stock of standard gauges and tools; his duties cover the checking of all tools and gauges, whether made in the factory or bought outside, together with the continual checking of all gauges in use.

4. *Ratefixer.*—Responsible for the piece-work rates throughout the factory, and estimations of cost for quotations.

5. *Shop Superintendent.*—Responsible for all bearing manufacturing and assembling processes, maintaining their quality and efficiency.

6. *Metallurgist.*—Responsible for all chemical analysis of material before issue, and for maintaining quality and output of the hardening shop.

7. *The Progress Group*—scheduling, records, materials, and works progress clerk—covers the multitudinous duties associated with planning the order of work and marshalling it through the works efficiently.



Works organisation chart.

8. *The Plant Maintenance Foreman* is in charge of all repairs to production plant and the usual millwrights' work in the factory, and assists the equipment superintendent with any surplus capacity at his disposal.

9. The maintenance of all electrical equipment, high speed vertical steam engines and boilers, and their efficient working, is in charge of the *Power Plant Engineer,* who also controls the yardmen and the watchmen.

10. *The Ball Plant Manager* is responsible for output and discipline to the works manager's office, and for quality to the technical department.

11. *The Works Accountant* has divided responsibilities, but so far as the purely "works" side is concerned he is responsible for the analysis of time tickets to provide accurate costings of complete units made in the factory.

This brief *résumé* of the principal duties of the chief executives can give very little idea of the manner in which these various duties and responsibilities are co-ordinated and controlled; to describe and discuss this fully a separate paper would be necessary.

Briefly, however, we may say that the mechanism is set in motion by the issue of a manufacturing instruction by the general management and to the works management specifying the size of bearing, quantity required, and rate of delivery to stores, together with any special instructions.

The office records indicate immediately whether the bearing in question has been made before or not; if not, the technical office is instructed to prepare designs, whilst if it has been made previously the records are consulted to ascertain if the necessary equipment is complete and in stock; where this is the case a manufacturing instruction is passed on to the scheduling clerk.

The shop schedules are run on a weekly basis, each department receiving a copy indicating the requirements per week from that department for at least four weeks ahead, the stock of parts in that department, and deliveries up to date, these details being brought up to date weekly; the weekly quantities called for are controlled from an intimate knowledge of the machine hours available on each group of machines and the time necessary for the corresponding operations on the bearing required. Thus, when a new instruction is issued it is a comparatively simple matter to ascertain whether there is available capacity to meet the delivery called for; the other condition to be filled is the supply of necessary material to time. This is controlled by issuing duplicate instructions to the material control section at the same time as to the scheduling department. The former then consult their records and report to the latter if material is in stock, or, if not, when it is expected to be available; where material is not in stock the necessary requisition is initialled and passed to the works management office for approval.

Should it be impossible, from consideration of equipment, machine capacity, or material deficiency, to meet the deliveries called for, the general management is informed, and a revised delivery date fixed.

A schedule covering all departments is issued to the shop superintendent, the works management, and the works progress manager; the last-named, who has charge of all work in the progress stores, keeps the work moving from operation to operation and department to department in such a manner as to meet the delivery requirements, and since he has no direct

control of operations the position calls for the exercise of much tact in dealing with the executive governing production and inspection.

Any serious hold-ups through material, equipment, or plant which cannot be remedied immediately are reported to the works management, where any necessary action is taken.

The movement of work between departments is noted on departmental invoices, duplicates of which are passed to the records clerk. The works progress clerk in each department also issues the work ticket on which is recorded the size of bearing, shop order, operation to be performed, number of pieces issued, and the piece-work price, etc.

Gauging inner race tracks with special indicator gauge.

This ticket accompanies the work to the inspection department, the particulars as to pieces passed, scrapped, and to be rectified are filled in after examination of the work, and from these details the operators' piece-work earnings are eventually calculated.

Analysis for Operations.—The works progress, on receipt of the completed ticket from the inspection department, transfer the details to operation sheets which are arranged under individual operations and passed to the records clerk.

From the figures of the records clerk the deliveries against scheduled quantities are filled in on the works management and other schedules, and a report on discrepancies passed to the

works management, who, when these are serious, make further investigations.

We can now revert to the point where an order is received for bearing or part that has not been previously made, for which, as stated earlier, the technical manager is instructed to prepare designs. These, after approval by the works management, are issued to the shops, ratefixer, equipment designer, and material control department, and at the same time the order is issued to the scheduling and materials department.

If the unit in question is of standard type, the issue of equipment drawings and supply of equipment is a matter of routine, as the equipment will follow well-defined lines. When, however, the unit is of a new type the detail design of equipment is fully discussed between the works management, equipment designer, and works superintendent, and approved before equipment drawings are issued.

In any case, once these drawings are issued, the equipment superintendent gives a promise of delivery of the details to the various departments; the materials control department gives from the design drawing a promise of delivery of the necessary material, and thereafter the machinery of scheduling and progress, etc., follows as previously indicated.

The records clerk has, as the basis for all his analyses and statistics, the departmental invoice and operation sheets previously mentioned, and supplies a number of returns to the works management, and generally to the department or departments concerned as well.

The principal information supplied is:—

(*a*) *Daily.*
- (1) Deliveries to stores.
- (2) Deliveries for the month to date.

(*b*) *Weekly.*
- (1) Deliveries to stores.
- (2) Output of the various departments and of various sections of some departments.
- (3) Machine hours worked corresponding to previous return.
- (4) Scrap and rectification corresponding to previous two returns.
- (5) Balance of stores in the various departments.

The returns, as well as being given in tabular form, are all graphically recorded in the works management office.

As in all other businesses, it is essential to keep the stock of raw materials as low as possible, compatible with economic working of the factory, and to provide a check to this. A monthly report is made to the works management giving actual stocks of material, the quantity required against instructions for the next two months (month by month), and the excess or deficiency of the stocks over or below the requirements.

As a final check on the manufacturing efficiency (judged from the financial standpoint), the works accountant keeps up to date a chart for the works management, on which is shown the cumulative cost of direct labour, indirect labour, salaries, overheads, and raw materials for each month against the value of the works output; needless to say, this latter curve must show higher values than the former, and it is the works' constant endeavour to make the difference between the two as large as possible.

THE DISCUSSION.

THE PRESIDENT proposed a hearty vote of thanks to Mr. Scaife for preparing the paper, and to Mr. Richardson for reading it.

The motion was carried with acclamation.

MR. RAYMOND MITCHELL said he was by no means a specialist in ball and roller bearings, although in the course of his engineering experience he had had various opportunities for observing how badly they behaved, notwithstanding that very great trouble had been expended in their installation.

With regard to this extremely admirable, very lucid and frankly stated paper, what struck him most, as an engineer, was the very plain and straightforward, although in some cases very subtle, manufacturing methods employed. For instance, he imagined that the chucking device for dealing with the gripping problem of rings accounted for what he knew to be the very fine quality of the Ransome and Marles bearing, as he had used those bearings in motor-car work. He did not believe that engineers who employed ball and roller bearings were, as a rule, sufficiently grateful for the truly marvellous workmanship that entered into this product, and as an engineer who happened to be somewhat obsessed at times by what he might call certain romantic attributes regarding engineering productions, or perhaps the artistic point of view, he frequently felt tremendously annoyed at the very casual manner in which such an exquisite piece of workmanship as a ball or roller bearing was treated. Since the war they had all been rather in the habit of talking very glibly of the fine unit of dimension such as 0·0001 of an inch, and Mr. Richardson had mentioned in the paper a unit of even 0·00001in. In reality, there were very few branches of engineering in which it would be commercial to work to such close limits as that, and even if they found the drawing office specifying the use of a ball or roller bearing to such limits, the works, at the very outset of the career of the machine, failed to take even the elementary precautions which would ensure correct mounting. That was a point of view which had been very strongly borne in upon him during his somewhat limited experience.

Another point was the question of lubrication, that also was ignored on a surprisingly large number of occasions. Anything greasy was presumed to be good enough to put in a ball bearing, and the man felt that he had done his job remarkably well if he had put in any available mixture which had been in a tin on the floor with the lid open. He had in his own experience come across instances where, as a result of that practice, the bearings on the hubs of heavy lorries had failed, and usually the designer, or the works, or any person was blamed for the condition of the bearings as a consequence, whereas in fact it was due to the carelessness of the person responsible for their use. He hoped that either Mr. Scaife

or Mr. Richardson would, at a later stage, deal with developments in the application and design of ball bearings. He happened to know that they were very keen students of tendencies in design in ball bearings.

MR. BELL referred to the statement in the paper with regard to hair lines on the steel used for bearings, and asked if the author had found these to occur with the mild case-hardening steels and in the highest alloy steels, which he had been using, and if he could give any information on that.

He would very much like to know whether that trouble had been eliminated. Another point which occurred to him, arising out of the paper, was that there seemed to be a considerable amount of scrap resulting from the manufacture of the bearings, which the author apparently thought it advisable to sort and store in order to be made up later into a special size of bearing. That was a practice he would have thought, in this branch of work, exceedingly undesirable, as it might lead to laxity on the part of the workmen, so that the amount of scrap would become generally larger than it should be.

He would like to know the exact reasons which had led the author to the adoption of that practice. In conclusion, he congratulated Mr. Scaife on his paper and upon the results which he had obtained. He knew this firm's bearings very well, having used a great many of them, and had always obtained extremely satisfactory results.

THE PRESIDENT said he understood Mr. Richardson to say that between 2$\frac{5}{16}$in. and 5in. in diameter the rings were made from bars. Was that right?

MR. RICHARDSON: No. Up to 2$\frac{5}{8}$in. and over 5in. diameter the rings were made from bar, but between those sizes they were made from tube.

THE PRESIDENT: The usual hot-rolled tube of the Mannesmann type, and not hot-drawn tube similar to gas piping?

MR. RICHARDSON: Yes.

THE PRESIDENT, continuing, said he would like a further explanation of the gauge described for measuring the track diameter when machining, in the first instance, the ball race track in the outer race.

He understood that this was adjusted to run on the outside of the chuck, and that the tool was set to gauge, and the correct diameter obtained in that way. He did not quite follow how this would eliminate the spring of the tool or the wear of the tool, and as it was to him a novel feature to measure cutting diameters in that way, a little more explanation of the method would be useful.

With regard to hardening temperatures, he had made a note whilst the paper was being read that the temperature of hardening was from 780 to 820 deg. C. for the chrome steel, which was then tempered again at 170 deg. C. That seemed to him a very delicate operation, and one which he could hardly reconcile with the question of die-cast cages around rollers.

His experience of any metal that could be die cast was that it must be in the neighbourhood of 600 to 650 deg. F., which was considerably above the re-tempering temperature, and he would like to know what precautions were taken to prevent interference with the heat treatment of rollers that were so die cast on cages. His

experience of ball bearings on die-cast cages in this way had been disastrous because of this very reason; it had been impossible to ensure that the balls could be sufficiently hard after the metal had been run around them in this way.

It seemed to him somewhat startling, in our present state of development with steel, to hear an eminent manufacturer like Mr. Scaife say that the only way to test surface hardness of a bearing was by scratching it with a piece of steel. He had heard many people in that room extol the value of scleroscopes and Brinell machines for this purpose, but he noticed that Mr. Scaife still relied upon the hardness test, in the first instance, by scratching it with a file, and finally by scratching it with a bit of steel. He himself had used the scleroscope very successfully on a great many pieces, and certainly in pieces of the particular form that had to be dealt with; in the case of bearings on flat surfaces it was fairly reliable, and gave an indication of the general surface hardness. Another thing which appeared to him very extraordinary, and he would like the author to illustrate the point, was that he employed so many capstan lathes on this work. One of the illustrations to the paper showed a workshop with two or three automatics and about twenty times as many capstan lathes, but he should have thought that with this type of product the automatic in some of its forms could have been much more economically employed. This certainly appeared to him as requiring some explanation. Another thing which appeared to him very bold, and one which he certainly would hardly dare have attempted, was the grinding and finishing of the outer races. The outer race was apparently finished first, and the track afterwards. It appeared to him that there would be fewer difficulties in the way if the track were finished first and the bearing mounted truly upon that track. It appeared to him, from his own experience, that this was the right way to do the work, and it would be very interesting to know why the reverse method was adopted.

Mr. A. Butler said he had been interested in the matter of cleaning ball bearings, although his interest was rather different from that of the author, because his work was to clean them after they had been greased. As a matter of fact, he could hardly imagine ball bearings going through the maker's workshops without getting dirt of some sort on them, and he doubted whether 40lb. air pressure would clean them under the conditions in which he had to handle them. Therefore he would like to know whether a particular type of air-pressure nozzle was used by the author, or whether there was any other process before the blowing out to remove the grit, because the bearings were sometimes in the shops a matter of weeks before they were finally sent out. They all knew what it was to try to keep these things clean, and they were not always very successful, and he failed to see how a ball bearing could be kept quite clean by air pressure alone. With regard to the fixture, which the previous speaker had also mentioned, for the machining of the ball track, and the indicator showing the size, he might be mistaken, but he thought he noticed in the illustration a Starrett indicator running on the outside of the chuck, which gave an interruption on the face of the chuck. Did the author get over that by running on the back shoulder?

Mr. Richardson said that was so.

Mr. Butler, speaking with regard to scrapping, said that was an

interesting problem to all of them, and he would like to know if the scrap was used only for testing hardness.

MR. RICHARDSON said no.

MR. BUTLER asked whether the drop test was applied only to the chromium alloy or to case hardening steel as well.

MR. RICHARDSON said it was applied to both.

MR. BUTLER said that was rather interesting, because he had had to test case hardening steel for fracture or strength, and it would be desirable to hear a little more about that if possible. He was also interested in the very careful description of the system of putting work through the shops at Messrs. Ransome and Marles' works, and it would be informative to some of them to know what the proportion was between the number of people employed in working that system and the total number employed in the shop. From what he had seen of the illustrations, the methods employed in manufacturing these ball and roller bearings were very simple and straightforward, and the inspection method certainly was unique. But the system for putting the work through the shops seemed to him to be rather unwieldy compared with the simple methods used in the actual manufacture of the bearings themselves, and it was for that reason that he would like to have some idea of the proportion of people employed on the two sides.

MR. S. G. MARTLEW said he also would like to record his appreciation of the paper, the illustrations to which carried him back fourteen months, when, with other members of the Institution of Mechanical Engineers, he was privileged to be taken over Messrs. Ransome and Marles' works, and follow through many of the processes of manufacture which had been described in the paper. In fact they did more than that, because they had seen some die-cast cages which had not been referred to at all, and he would like to know whether they were being turned out in large quantities at the present time. There were several things which caused doubts to arise in the minds of one or two of them with reference to these die-cast cages, but nearly all these doubts had been removed by actual test before they left the works on the occasion of the visit. Personally, he had had a good deal to do with the use and testing of ball bearings in actual practice, and had come up against one or two disastrous breakdowns of machinery, due to broken balls. He put it to the author that, taking an ordinary bearing, not a roller or ball bearing, if a mishap occurred to it in the case of an ordinary piece of machinery, something fairly serious might arise, but when ball and roller bearings were on a lorry on the road, and say a roller broke, then something very bad indeed was bound to happen, because a new back axle, or something of that sort, might be required as a result. Therefore, he would like to know what advance had been made in trying to prevent any such disaster as he had hinted at. At the same time, he would like to bear testimony to the great saving that was obtained by replacing the old-fashioned line shaft bearings with ball or roller bearings. In his very young days he had helped to carry out trials on a mill where there was a great deal of horse power being lost in transmission. When they came to investigate they were surprised at the large amount that was lost, and the test was made a second time to make sure. It was found that the amount of power lost was of the order of 60 per cent. from the time the power was sent out from the mill-driving engine until it was de-

livered at the various machines. That loss of 60 per cent., of course, was a very great amount, and it was lessened very considerably by adopting much more modern methods, incidentally straightening the shafts, and seeing that there was adequate lubrication, because he did not suggest that the whole of the loss was due to not having roller or ball bearings. A great deal was due to the shafting being out of alignment, and generally neglected, which sometimes did happen in a factory where they were too busy turning out stuff to have a chance to attend to the mechanical part of the transmission. The paper did not say very much about roller bearings, and he personally would like to hear something regarding roller bearings and thrust bearings. He knew that experiments had been conducted for some time concerning the maximum horse power that could with safety be transmitted. In the case of a thrust bearing, there was, as an extreme instance the thrust bearing on a large marine engine. Up to the present the Michel thrust block appeared to hold the field, but he believed a thrust could be made of the roller, or probably of the ball, type. He would like to know what advance had been made in that connection during the past year or so, and also if the author could say, without trespassing upon any trade secret, what was the practice of Messrs. Ransome and Marles with regard to the relation between the radius of the ball and radius of the track. One other thing he would like to mention, as it had not been referred to, was that the average ball bearing of to-day (made not only by the eminent firm of which so much had been heard that evening, but by other firms of probably equal eminence in this country) was so accurate that the balls could with safety be used as gauges. He himself employed them as gauges in munition manufacture to a very great extent, as well as on other jobs, and had very frequently found them of great service. That was ample testimony to the very great degree of accuracy which was now obtained in the ball bearings supplied by a good ball-bearing firm.

Professor D. A. Low said that just over a year ago he had had the pleasure of going over Messrs. Ransome & Marles' works at Newark, and had an exceedingly instructive and most interesting visit. He was particularly struck with the neatness and tidiness of the whole works, and the superiority of the workers. He wished to congratulate the Institution of Production Engineers upon having had such a paper. Those who had spoken so far did not seem to have appreciated this, or perhaps they could not find words in which to express it, but it was a very remarkable paper, and well suited to the Institution. They were indeed grateful to the author for the minuteness with which he had described the manufacture of ball and roller bearings.

Mr. Murphy said the thanks of the Institution were due to Mr. Scaife for having put before them so very frankly many facts which, at any rate to a large extent, had never been given to an Institution before. The ball-bearing industry had always been something of a mystery trade. During the war he came across one or two instances in which there was a secrecy which perhaps was not entirely directed to keeping secrets out of the enemy's hands. Therefore, the frank way in which the information had been placed before them in this paper was extremely generous, to say the least. He had noticed in one of the technical journals a month or so ago a statement by a member of the staff of the firm of Messrs. Ransome & Marles, in which reference was made to the obsolete and terrible type of cycle

ball bearing. He (the speaker) happened to be the person who, for many years, thought there was a place for the cycle type of ball bearing. He did not wish to digress from the subject of the paper, but Mr. Richardson happened to mention to them, in reading the paper, the difficulties in the manufacture of the magneto bearing. The magneto bearing was probably a most elaborate form of the cycle type of bearing, but it did not possess the difficulties of the cycle bearing which the ordinary designer was up against. Therefore, it would be a very great advantage if they could get over the difficulty of having to combine radial bearings with thrusts, and he had noticed a tendency on the part of one or two well-known designers to adopt the old cycle type or magneto type of ball bearing in quite important applications, as, for example, the combined radial and thrust on the bevel pinion of the back axle in powerful car design work. That was by a man with an established reputation, and perhaps Mr. Scaife would let them know whether the objections to the manufacture of this type of bearing were directed against the tendency of the ball to spin in use, or whether it was really a manufacturing difficulty that accounted for the prejudice against the use of this type of bearing. There was one other point which interested him as the paper was being read. As an outsider he had always cherished the fond belief that ball-bearing manufacture was such an extremely accurate job that it needed the methods of the laboratory in production, and that if one went round a ball-bearing works one would find all sorts of wonderful gadgets with electrical contact devices for measuring the fine degrees of accuracy required. So far as he could see now, however, this was not the case, and perhaps the author would not mind telling them whether such devices had been used in actual manufacture, or whether they had been found to be cumbersome?

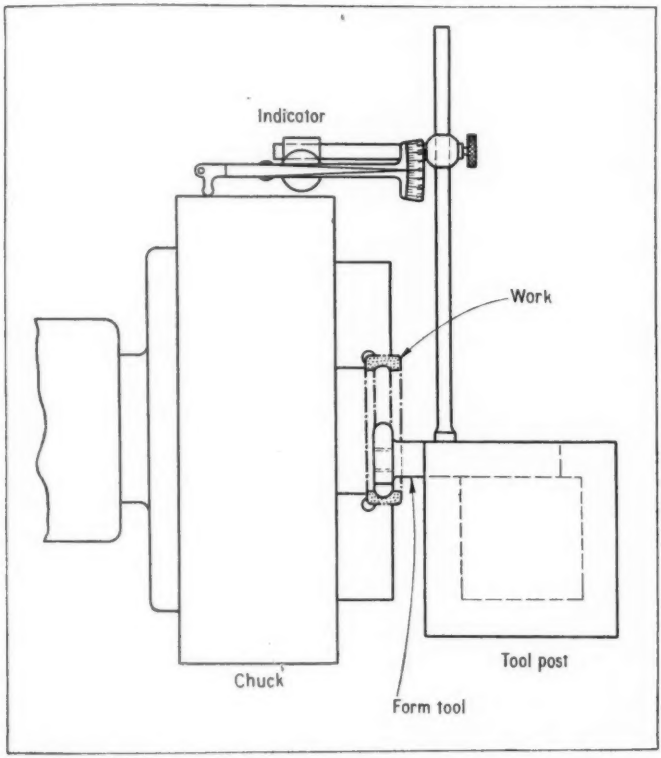
Mr. Hillier, speaking with regard to hair lines, asked whether some of them were not surface cracks or marks developed in the grinding operation. Personally, he had found this to be the case in a large number of instances. He understood Mr. Richardson to say that they had eliminated the whole of the polishing and lapping process. He believed with the Hoffmann Company it was usual to polish their balls and bring them to a very high degree of accuracy by rubbing them with chamois leather, and he would like to know whether that was eliminated altogether with the Ransome & Marles' product. In the States they had very cheap roller bearings where there was no end thrust required. They hardened the bars first, and then cut them into short lengths; there was practically no machining at all on the rollers. He believed the bars were hardened in short lengths and ground, and cut off with an elastic wheel, giving an exceptionally cheap roller where no end thrust was required. He knew that such roller bearings were used on the small end in motor cycles like the "Indian."

Mr. Martlew asked for information as to the anticipated life of a bearing. They all knew that fatigue took place in metal, as in other things, and there must be a limit of life to a bearing, even supposing no great wear was shown. He would like some information, if possible, as to what that limit was likely to be.

Mr. Scaife, replying to the discussion, said that Mr. Richardson had had a great deal more to do with the paper than the mere reading of it.

With regard to hair lines, mentioned by Mr. Bell, they were present

with mild steel as well as with chrome steel, and he had not yet found any sort of bearing steel in which the makers had been successful in eliminating hair lines. Replying also to Mr. Hillier on the point as to whether hair lines were really in the steel, or whether they were put in afterwards, his experience was that they were in the steel. They were extremely small slag-holes, which had been lengthened out in the rolling process.



Detail of indicator attachment for turning tracks in outer rings.

As to the President's question with regard to the method of measuring the track in the machine, he would explain that by a diagram (see above).

THE PRESIDENT: That is perfectly clear now.

MR. SCAIFE, dealing with the President's question as to the hardening temperature, and the subsequent tempering, and why the making of the cages did not soften the rollers, said that, as the temperature of the molten metal was only about 300° C., and the solidification

was practically instantaneous, there was no tempering effect. The ordinary ball and roller journal cages were not made with the balls cast in, but thrust race cages were so made at one time, and the firm's patent roller bush has always been cast with the rollers in position, and with no perceptible tempering of the rollers.

Regarding the method of testing hardness and the use of the scleroscope, mentioned by the President, he used rather to favour that instrument himself, but certain results that he had obtained from time to time had rather upset his ideas on that point. The scleroscope was all right in the hands of an expert who understood the nature of the instrument, and when the particular application to which it was being put was known, but as an instrument for general use it was not much good on this class of work.

He had a curve of readings obtained on a ball, using the scleroscope, which gave exceedingly strange results with regard to hardness. For instance, he got a result on a $\frac{7}{16}$in. ball which gave a reading lower than the value of the ball before it was hardened. In the case of a $\frac{5}{16}$in. ball it gave a reading which was higher than normal. That result, however, was not the hardness at all; it was some sort of harmonic action of the ball. It had something to do with the vibration of the ball in the loose state, or the elasticity of it. When the ball was clamped, or put into a vee, there was a different effect. It all depended upon how they clamped the ball, and what sort of mounting they had.

Mr. Butler asked if a special hammer were used.

Mr. Scaife said no.

Mr. Butler suggested that this might upset the reading.

Mr. Scaife said he had not thought it worth while to try this, as there, again, the result would be connected with the shape of the hammer, and would have no meaning apart from this particular application. The difficulty of using the scleroscope in this work was that for every different application it was necessary to have a different numeral; therefore, it was not an instrument which could be put into the hands of unskilled people, and a great many of the men employed on this work were not what would be called fully skilled. They were put at one operation, and had to do that well, and it was impossible to teach them how to test for hardness, using a variety of numerals indicating the same hardness.

As to capstan lathes, mentioned by the President, it so happened that there was a large number shown in the illustration, but they were not all used for bearing manufacture, and, as a matter of fact, the slide showing the automatic shop had been, unfortunately, crowded out.

The President's point with regard to grinding the outer race tracks before the top diameter was a good one. When he first started making ball bearings he had thought it should be done in the way the President had suggested, but there were great difficulties in the way, and one was the difficulty of making a true surface locating from some surface which was untrue. If they ground the track first, there was the difficulty of locating precisely from this in grinding the top diameters; also, on account of the top diameter not being precisely round, the ring could not be gripped by that diameter for grinding tracks.

There was a roughing and finishing operation on the tracks, and there was not enough material to finish grinding the tracks, with

the present allowance of one or two thousandths of an inch, and there would be some difficulty in truing from the rough-ground track if the spinning process were employed. They would spoil the track in spinning it true. A very much simpler process was the one adopted, because they could put them in the chuck as many times as they liked without affecting the accuracy.

THE PRESIDENT said it could be done by using the mandrel as described for grinding tops.

MR. SCAIFE said that was so if a truly round track could be obtained, but for the reasons stated it was not practicable. Moreover, there was nothing to be gained by reversing the order of the operations.

MR. BUTLER mentioned that on the outside, apparently, the author was tied up with a given tolerance, but on the inside there was a selection of three different sizes.

MR. SCAIFE said it was all a matter of concentricity. There would be some difficulty in grinding the track round if it were not supported all the way round. If it were dealt with otherwise, then bad results would follow, if, for instance, the top were not held firmly.

Replying to Mr. Butler's point on the simplicity of the operations, Mr. Scaife said that the simplicity was more apparent than real. No doubt Mr. Butler referred to the "single purpose" nature of the plant, which was certainly the most economical for this class of work.

As to the cleaning of the bearings, he was aware this was a matter which concerned Mr. Butler intimately, because he knew the bearings Mr. Butler used and their work. They had to be exceedingly clean, but he could assure Mr. Butler that he did not know of a better method of cleaning them than with high-pressure air. He himself had tried every system known; he had washed the bearings out with all kinds of liquids, and he was speaking from experience when he said that there was no better method than high-pressure air. He believed Mr. Butler's difficulty was due to the fact that he did not use a sufficiently high pressure, as, indeed, he had advised Mr. Butler's people only recently. If they would use 40lb. pressure they would clean the bearings effectively. Of course, the bearings had to be washed out first, because in going through the shops they were bound to accumulate a certain amount of grit, but the last operation was to blow them out with high-pressure air, as had been described.

With regard to testing fractures, it was only the rings from the turning shop that were used for this purpose. He employed pieces of exactly the same material, and took pieces out of the steel store if there were not sufficient from the turnery. It was not only necessary to use pieces of the same material, but also of the same section, because otherwise results were not uniform.

As to the proportion of indirect labour mentioned by Mr. Butler, that was, roughly speaking, about equal to the direct labour; as indirect labour he included everybody except those working on the actual machines. Answering Mr. Martlew, he said that his firm were not making any die-cast cages at all now.

With regard to heavy duty bearings on lorries, he did not think that anything had ever yet been discovered to prevent bearings failing under some conditions. Any bearing, if overloaded, would break, but, on the whole, he thought bearings were very much better now

than they were. Size for size, bearings now would stand a much higher load than they did some years ago.

With regard to line shaft bearings, he had shown a line shaft hanger in one of the illustrations, which had roller bearings.

Various questions had been raised by various speakers on matters relating to design of bearings, but these were outside the scope of the paper and could not be dealt with in the time available.

Reference had been made to the use of balls as gauges; that was all right for standard sizes, but in their works they did not use any gauges of that sort. All their gauges were limit gauges.

Coming to the secrecy of operations, mentioned by Mr. Murphy, his firm had made no point at any time of keeping their methods very close, except, perhaps, methods of roller manufacture and that sort of thing. They had published pretty well all that they had done, and although in the past, perhaps, they had not published everything, it had been decided now that on the whole it was the best policy to publish full details and let users see the sort of difficulties that had to be contended with, because then, perhaps, users would treat bearings with a little more respect than they did.

With regard to Mr. Murphy's question as to the cup-and-cone bearing, there was not much wrong with that if it were well made. It was the same bearing, in principle, that was used on Messrs. Ransome & Marles's grinding spindles, and as a high-speed bearing there was nothing like it. R. & M. ran their ball-bearing spindles up to 30,000 or 40,000 r.p.m., and it was a cup-and-cone bearing that was used. Everything depended upon material, accuracy of workmanship, and cleanliness, and these features were not obtained in the highest degree with the ordinary cycle bearing. If a bearing manufacturer were to make the cups and cones and design the bearings there would not be any trouble about it whatever. On the whole, however, a standard journal bearing was a better proposition.

A MEMBER asked whether the cup-and-cone bearing for a certain load and speed would actually cost more if tackled in one operation by a ball bearing firm than an equivalent radial and thrust bearing.

MR. SCAIFE said he thought it would (as they made them for grinding spindles), unless they were made in very large quantities, such as 10,000 or 15,000 lots.

With regard to grading the size of balls, no difficulty was found whatever in using the minimeter, which would test balls to a two-hundred-thousandth of an inch. This was not an ordinary minimeter, but a machine made specially for the job, and they always had a standard ball as a check.

THE PRESIDENT said they were all exceedingly grateful to Mr. Scaife for the conscientious way in which he had answered all the points in the discussion and advanced their knowledge of these matters. It was exceedingly gratifying that they should have heard from him that secrecy in these processes was taboo, because it was by cultivating that idea among men in his position in other industries that they might eventually hope to show them that, if they cast their bread upon the waters, it would return to them after many days.

After the close of the meeting the members inspected a large number of exhibits which had been brought to the meeting by Mr. Scaife.

COMMUNICATION.

Kindly allow me to point out one or two errors which have occurred in the reporting of my remarks on the discussion of Mr. J. D. Scaife's paper on "Ball and Roller Bearing Manufacture," recently read before the Institution of Production Engineers.

(1) For—"He believed with the Hoffmann Company it was usual to polish their balls and bring them to a very high degree of accuracy by rubbing them with chamois leather," should be read: ". . . to polish their balls by rumbling or barreling them with small pieces of chamois leather to obtain a high degree of finish."

(2) With reference to my remarks concerning the manufacture of a cheap roller as used in some roller bearings in America, by the utilisation of rods of steel rolled to size plus a grinding allowance, hardening them, and parting off the rollers with an elastic wheel, I am reported as stating that such rollers were used in the "small end" of the "Indian" motor cycle, whereas, of course, "big-end" should have appeared.

W. J. HILLIER.

Lewisham, S.E.13.

THE
INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting of the Institution was held at the Institution of Mechanical Engineers on Saturday, October 15th, 1921.

The President, Mr. Max R. Lawrence, occupied the chair.

Mr. R. Waring-Brown, of Coventry, Member of Council, delivered a paper dealing with the "Production of Spur Gears."

At the close of the paper considerable discussion took place, and the meeting closed with votes of thanks to Mr. Waring-Brown and to the Institution of Mechanical Engineers for loan of the hall.

THE PRODUCTION OF SPUR GEARS.

By Mr. R. WARING-BROWN, A.M.I.A.E., F.R.S.A. (Member of Council).

The manufacture of spur gears is of absorbing interest, particularly in regard to the requirements of high-speed mechanisms, such as are usual in automobile and aircraft construction.

The operations involved in the production of such gears are so numerous and scientific, and practical knowledge is so necessary to secure first-class results, that specialisation on the subject becomes absolutely essential.

It will be obvious that a subject embracing such a large field of manufacture cannot be adequately discussed in all its branches in a short paper such as this. It is the intention, therefore, to consider production in relation to the methods involved in the cutting of high-class spur gears only.

The chief requirements which confront the manufacturer are:—

(*a*) The reproduction of accurately formed teeth; (*b*) an economical rate of output; and (*c*) uniformity of production.

The involute form of gear teeth, quite irrespective of its advantages and disadvantages, is now recognised as a standard for all varieties of meshing gears—external, internal, spur, bevel, spiral, spiral-bevel, or worm type.

First—the problem confronting the manufacturer is that of producing accurately formed teeth which will ensure the satisfactory working of the gears; second—the rate at which such gears can be produced must be rapid, in order to keep down the cost of manufacture; and third—uniformity of output is absolutely essential.

The last consideration seems to be assured, if accuracy in reproduction of the involute-tooth profile can be realised—for the involute curve is of mathematical exactitude, not susceptible to variation.

Unfortunately, a true involute set of gears cannot be made on the so-called standard 14½ deg. system, or even on the 20 deg. system, on account of the unavoidable interference; hence the profile of such teeth may depart from the true involute curve for the greater part of its depth.

Therefore, where a system of teeth is adopted, based on a

fixed pressure angle, it would appear to be essential to standardise the necessary modifications or corrections to the involute curve, as well as the form of the tooth, in order to ensure uniformity of output.

Limitations of the Involute System.

The limitations and inaccuracies of the involute tooth system are due to the fact that in many ordinary gear combinations the teeth of the respective gears, if of pure involute profile, would interfere and would not run together on account of advancing teeth meeting obliquely, tending to force the teeth out of engagement. Particularly is this true where small numbers of teeth are utilised. The fact that gear units usual in automobile work necessitate the use of wheels of small dimensions working at high peripheral speeds also renders production for such purposes one of considerable difficulty.

In the involute system a normal from any point on the true involute profile of a tooth is tangent to the base circle of the gear, and the path of the point of contact throughout engagement—or the line of pressure—is a straight line passing through the instant axis of engaging gears inclined to the plane of common tangency at an angle. This is known as the angle of obliquity, or pressure angle—the variation of which has a considerable effect upon interference.

It is this peculiarity of the involute system which renders it possible to vary the centre distances of a pair of gears, within limits, without affecting the tooth action, because the increase of centres is only equivalent to enlarging the pitch diameters without alteration of the respective base circles, the characteristics of the teeth being unaffected while the pressure angle is slightly increased.

This is the chief merit of the involute system, for it allows for a certain adjustment of centre distances and slight inaccuracies in manufacture of other details without destroying the smoothness of action. Involute interference varies inversely with the obliquity of the teeth, for which reason the 20 deg. system has displaced to a great extent the 14½ deg. system in high-class work.

It is often suggested that gears of the 20 deg. system show a decreased efficiency in transmission, due to the greater axial thrust developed, but the writer's experience does not bear this out.

The adoption of the more oblique tooth is the logical method of avoiding interference.

Avoidance of Interference.

It is obvious that the avoidance of interference by increase of pressure angle has its limitations, consequently modifications

are introduced to remove those portions of the tooth profile which develop interference, although, unfortunately, the pure involute curve is thereby destroyed.

Interference occurs whenever a gear combination is such that the point of tangency of the line of pressure with the base circle of the pinion lies within the addendum circle of the engaging gear; when the point of tangency falls on or outside the addendum circle of the meshing gear, interference is avoided.

It will be seen that there are three factors affecting interference—the number of teeth, the gear ratio, and the pressure angle of the teeth. The limitations of the involute system, due to the question of interference, are therefore very serious and must have considerable influence on economical manufacture.

It is essential that the factors determining interference be carefully studied, in order that the advantages and disadvantages of the various methods of commercial gear-cutting may be weighed against one another.

There are two primary methods by which surfaces may be reproduced, that is, on the forming and on the generating principles.

The forming principle in relation to gear-cutting consists in cutting the individual tooth spaces with a milling cutter conforming in profile to the shape of the finished tooth.

In order to understand fully the action of generating gear teeth, it is helpful to approach the subject from the point of view of the "moulding-generating" process, though that is not yet a practicable method. In this, assume a hard gear to be rolled in a plastic blank, such as wax, the gear and blank being mounted on arbors and rotated at the correct velocities, corresponding to the gear diameters, then the teeth so moulded would work correctly with those of the hard gear.

It may here be noted that the Anderson moulding-generating process of rolling a gear having correctly formed teeth into a blank heated to forging temperature has made considerable headway in the United States.

However, the usual application of the generating principle to cutting metal gears entails the use of tools provided with hardened cutting edges, advancing in a line parallel to the axis of the tooth space, in order to remove metal as the blank is rotated upon its axis.

Forming Gear Teeth.

Theoretically speaking, in order to produce accurately proportioned gears by the forming method, a different pair of cutters is needed to produce a pair of gears of a certain number of teeth of defined pitch and angularity. This is considered impracticable, because it entails an unwieldy number of cutters. To reduce, as far as possible, the number of cutters required,

compromises have been made by re-establishing standard pitches and by using each cutter of a series of numbers of teeth.

Further, by standardising the involute curves used for tooth profile, the so-called interchangeable gear system was adopted wherein all involutes have the same pressure angle.

The fixed angle, together with standardised addendum, dedendum, and tooth thickness, made it possible to cut all gears, ordinarily called for, with a comparatively small number of cutters; a set of such cutters consists of about fifteen, to cut teeth from twelve to a rack.

A little consideration of the primary principles of gearing discloses the fact that if a cutter is suitable for, say, thirty-one teeth, then it cannot be correct for thirty-two, thirty-three, or thirty-four teeth, for the curvature of the involute profile changes with the number of teeth. Hence it will be seen that a disadvantage of the forming method lies in the inaccuracy of the tooth forms produced.

Admitted that modern milling cutters are made with mathematical precision, this does not mean much, since this accuracy is true only for the particular number of teeth for which the cutter was calculated. Since, however, it is usual to use a cutter over a series of numbers of teeth, there can be no mathematical accuracy for the majority of gears. The inaccuracies due to this cause are greater than commonly supposed, and cause—at high circumferential velocities—considerable acceleration and retardation of motion, with consequent noisy running.

In any case, no certainty is assured that the gears produced by the cutters will operate without interference, for it is just as difficult to produce sets of involute cutters of standard profile for gears of different numbers of teeth as it is to produce a set of limited number of series cutters.

Production by the forming method necessitates that the ends of the gear teeth in certain gears be modified to enable them to mesh. Sometimes recourse is made to using a cutter belonging to a gear having a smaller number of teeth, so that the tooth becomes more pointed, as it should be, and thus the relative path of the tooth just clears the flanks of the pinion teeth.

However, the involute tooth has to be modified to enable certain gears to operate without interference, but the modification necessary is not that of rounding off the teeth by the method described, or of destroying the involute curve in the vicinity of the addendum circle, as has been done in gears machined with formed cutters.

The chief advantage of the extensive standardisation outlined is that of cheap manufacture, which is, of course, a most important factor. Economy can be practised in the forming method to an extreme degree by gashing or stocking out the tooth

spaces all round the blank before bringing the actual cutters into operation.

This has three advantages, in that much time is saved, the life of valuable cutters is considerably prolonged, and local heating is diminished. The gashing is sometimes carried out with cutters that mill a simple groove, which is the least satisfactory, or with a shouldered cutter, which is an advance on the previous method.

The best method is to use a stepped cutter, because the actual tooth forming is reduced to the minimum possible. In some small gears another economy is effected by cutting teeth so as to omit every other tooth, obtaining a better distribution of heat round the blank and avoiding distortion.

The Eberhardt system of multiple-cutters employs several cutters mounted side by side, their form being modified to suit the blank curvature of the work in hand.

The position, then, with the forming method is this—that economical manufacture is assured, that uniformity of output is satisfactory, but that correct and accurate tooth profiles cannot be assured with the series-cutter method.

The Planing Generating System.

The section of a gear of an infinite number of teeth is a rack, and in the involute system the profile of the rack-tooth is a straight line at right-angles to the line of action.

The curvature of the tooth profile vanishes, and the straight side-tooth is of the type which can be most readily, cheaply, and accurately reproduced by mechanical means, i.e., a simple, straight-sided, V-shaped cutting-tool accurately conforming in section to the shape of the rack tooth-space being employed.

Such a master form-cutter is the basic tool used in all systems of gear-tooth generation, the earliest of which was the Bilgram. The principle upon which this machine operates is shown in fig. 1. The tool is of wedge-shape section, conforming to the exact tooth-shape of a rack, of pitch, and angularity of teeth to be generated, and reciprocates rapidly.

At the same time, the tool travels in one plane from one side of the gear-blank to the other, the gear-blank, meanwhile, turning upon its axis at a space for its pitch circle equal to the speed of the traverse travel for the reciprocating cutter. exactly as a gear would rotate if operated by an advancing rack.

Obviously the reciprocating tool cuts a tooth space of pure involute curvature, completing the operation during the side travel of the cutter. A similar cycle of operations is repeated for each tooth space cut, and with only one cutting tool the gear blank has to be indexed over the necessary distance between productive operations.

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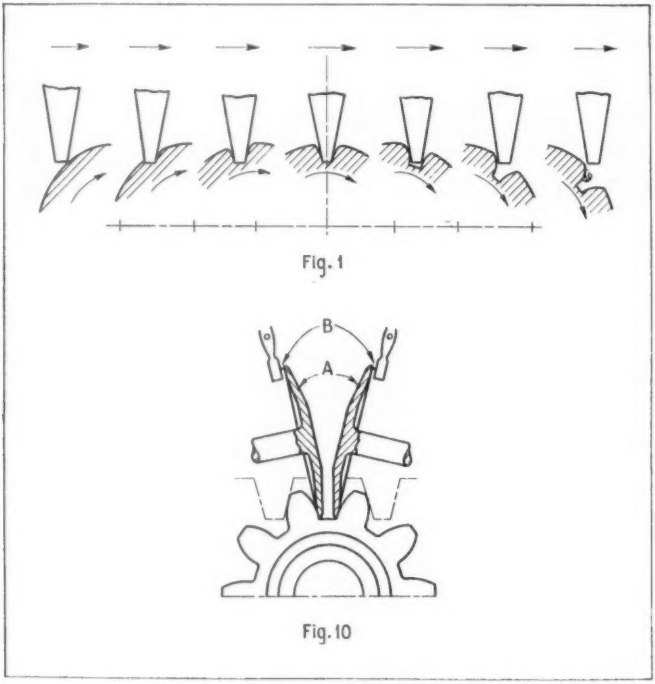
In this manner the action of a gear working with a true involute rack is reproduced, but as the rack has only one operating tooth, and there are no adjacent teeth to obstruct the advancement of the gear, the limitations placed on the involute system by tooth interference are neglected.

Hence gears generated by this basic method with teeth of pure involute form may be incapable of working together, because



Figs. 1 and 10.

of the interference which may be developed, and, therefore, have necessarily to be modified.

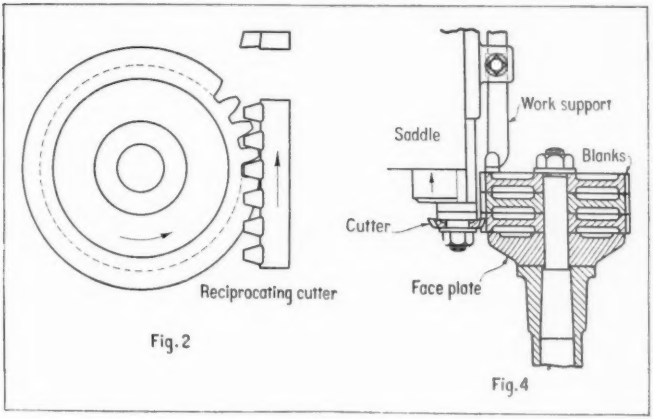
There are, of course, innumerable applications of this principle of planing-generating, some of which consist of an actual length of rack comprising several teeth, forming a cutter which reciprocates, while the rack and wheel blank are fed in the intervals of reciprocation as before. Such a cutter is shown in fig. 2, in which all the teeth on the blank are being shaped simultaneously.

It will be observed that the bottom teeth are always roughing and the upper always finishing; since, therefore, the upper teeth are subjected to less severe wear than the lower, they retain their capacity to finish accurately.

Factors Determining Interference.

A fundamental principle of gearing is that which demonstrates that interference can only be avoided by proportioning a pair of gears so that the point of tangency of the line of pressure with the base circle lies outside the addendum circle of the mating gear.

A rack is considered as a gear with an infinite number of



Figs. 2 and 4.

teeth, and it will be evident that no interference between the gear teeth of pure involute form and a standard rack can exist until the number of teeth of the gear acting as the pinion exceeds some definite number.

With the standard $14\frac{1}{2}$ deg. system interference occurs in any gear having less than thirty-five teeth, while interference commences in rack combination in the 20 deg. system, when the pinion has seventeen teeth.

A gear with a small number of teeth may be generated with a single rack-tooth, and its teeth of pure involute form will not interfere with the teeth of a standard rack or gear having teeth of similar pitch and pressure angle. Obviously, gears which will operate with the standard rack without interference will also work together.

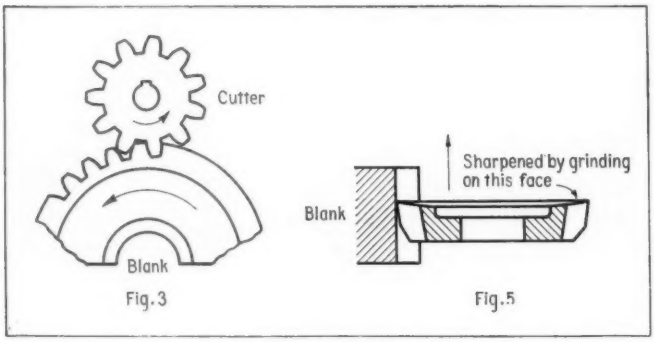
The Shaping-Generating System.

The Fellows generating system, as shown at fig. 3, will now be dealt with. The reciprocating cutter of this method is of actual pinion shape of accurately formed teeth on the involute system, hardened, relieved, and provided with cutting edges.

In operation the cutter shown at fig. 4 reciprocates axially across the face of the gear-blank being generated, rotating upon its axis, as would a pinion actuating a mating gear, while the blank is caused to revolve at a proportional speed, thus reproducing the action of a pinion and gear of similar speed ratio.

Suitable mechanisms control the movements of the cutter and gear blank, and the result obtained is exactly similar to that of the moulding-generating principle.

The profiles of such teeth are of pure involute form up to the interference circle, and are correctly modified between the inter-



Figs. 3 and 5.

ference and addendum circles, for, since the teeth are generated by absolutely accurate form cutters, the modification cannot be other than correct.

The modification of tooth profile over those portions developing involute interference consists in a progressive increase in the obliquity of the involute curve, for each individual point on the modified profile is also a point on the involute of a specific curvature, as it is a point of normal contact with a straight line tangent to a circle concentric with the base circle of the gear.

This system generates with the utmost uniformity accurately formed teeth of a standard involute profile.

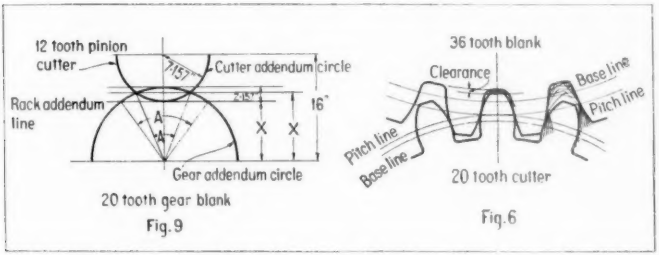
The crucial point of the system is, of course, the cutter, the principle of operation being shown in fig. 5.

It has been stated that the shape of the gear-tooth inside the base line was non-involute and indeterminate. This shape is determined by the shaping-generating method, as illustrated in

fig. 6, which shows a twenty-tooth cutter in mesh with a thirty-six-tooth blank. In the tooth-space on the right is shown the successive positions occupied by the tooth of the cutter as it rolls into and out of the tooth-space. The cutter is extended beyond the length of the gear-tooth which it represents, in order to cut deep enough into the tooth-space to form clearance. The points of the cutter teeth are slightly cornered to avoid rapid wear, and in rolling into and out of the tooth-space these cornered points of the cutter shape out the fillet, leaving a round of considerable radius, which materially strengthens the tooth. All the finishing below the base line is done by the points of the cutter teeth, and not by the involute portion of the cutter tooth outline.

The teeth of the cutter are themselves generated, but the operation is somewhat complicated, in that the teeth have to be hardened and ground, in order to render them effective.

In producing this tool the teeth are roughed out, the cutter



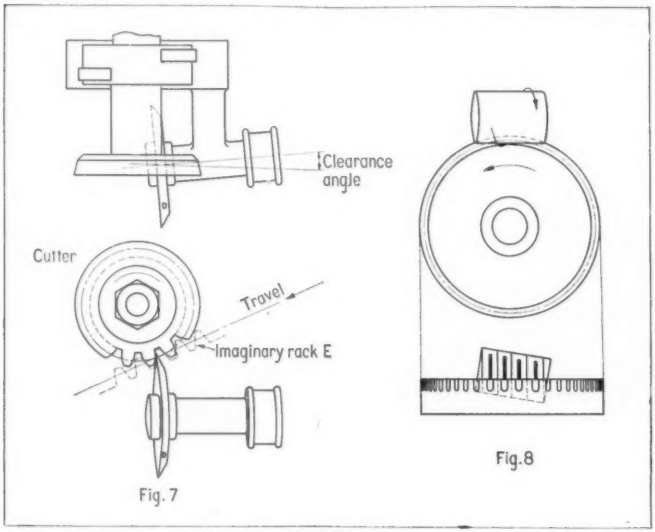
Figs. 9 and 6.

hardened, and the correct form given to it by grinding, as shown in fig. 7, with a wheel having a flat face set at the angle of the rack tooth selected as the basis. This being rotated, the cutter is rotated also and rolled past it in a definite relation. The motion of the cutter is produced by steel tapes wrapped upon a disc representing the pitch diameter of the cutter. One side each of the teeth is ground first, and afterwards all the other sides. The teeth are not backed off, as for a milling cutter, but an equivalent relief is imparted during the grinding of the cutter. In doing this the face of the grinding wheel is set at a small angle (as illustrated) with the axis of the spindle which carries the cutter. The result is that the teeth are sloped slightly, one side of the teeth being a portion of a right-hand spiral, the other that of a left-hand spiral.

It will be seen that the outside of the cutter is also bevelled off sufficiently to preserve the correct relations between the pitch, thickness, and the addendum.

It will be evident that the flat surface of the grinding wheel replaces the straight cutting-edge of the reciprocating rack-tooth cutter of the planing-generating type, and this roughed-out cutter rolls over the grinding wheel in a plane parallel to the line of pressure, instead of the rack-tooth cutter travelling from side to side of the cutter blank (as in generating gears by the fundamental planer method), the principle being exactly the same.

It will be noted that the cutter is sharpened only on the face, and that consequently it becomes reduced in diameter to a certain minute extent; but as the involute curves for the entire



Figs. 7 and 8.

length of the cutter are generated upon the same base circle, the teeth generated by the cutter, as it wears, are always alike, which results from the fact that the base circle is the generating surface in involutes.

The importance of the flat tooth of the involute rack can now be appreciated, as it enables the tooth curve to be generated from a surface which is easily obtained and accurately maintained by a cutter generated without a copying process of any kind, giving a true and originally developed involute outline to each tooth.

Comparing the single rotary cutter with the planing-gener-

ating and the shaping-generating systems in respect to speed of generation, it is apparent that the latter method is easily first, as several cutting teeth—usually three—are in operation at the same time (see fig. 3).

The several engaging teeth are not removing material uniformly, it is true, and the single-rack tooth cutter does not remove the same weight of chip on each operating stroke, but the total amount of material removed by the shaper-cutter per stroke—several teeth functioning—is considerably greater than that removed by the single cutter even when the latter is most efficiently working.

In fact, the machining rate of the gear-shaping cutter exceeds that of a rotary-disc cutter machining one tooth at a time, although the cutting section of the former is intermittent, while in the latter the machining is virtually continuous while the cutter functions, time being necessary, of course, for back indexing.

An interesting point in the manufacture of the pinion-cutters is that the blanks are roughed out by rotary form cutters preparatory to the hardening process, and are not generated, as might be supposed.

The reason for this is that the rotary cutter removes material more rapidly than can the generating cutter, and for roughing out, the accuracy of the forming cutter is sufficient.

The hardening process is liable to distort to some extent the profiles of the cutter teeth, which are corrected by means of a grinding generation.

The position in reference to the shaping-generating method resolves itself into this, that uniformity of output is assured, that absolutely correct tooth forms are obtainable, and that the relative productivity of this method is greater than any other already touched upon.

The Hobbing Generating System.

If it were practicable and feasible to replace the single rack-tooth cutter of the planing-generating system with a series of accurately proportioned cutters in the form of a reciprocating rack-section of sufficient length, and to actuate such a cutter in a manner similar to that of the single-cutter, reciprocating across the face of the gear blank, and at the same time advancing as if actuated by the rotating gear, teeth of standard involute form would be generated on the gear blank in a manner exactly as performed by the reciprocating pinion cutter in the shaper method.

The gear teeth so formed would be uniform, correctly modified to avoid interference, and precisely generated at a rapid rate of manufacture. Such generation is impracticable, however, but a hob, which can be assumed to be a spiral rack, can

replace the series-rack-tooth reciprocating cutters, and a similar result be obtained.

This is the principle of the hobbing method of gear-tooth generation, based on the same primary principles as govern the various other systems, viz., cutting gears with such a number of teeth as are not subject to interference. The main advantage of this system over the series-cutter method with respect to manufacture is that for all sizes of gears of the same pitch only one cutter is necessary. Although the worm-shaped cutters are, individually, considerably more expensive than the ordinary rotary cutter, the whole set is cheaper, covering as it does all the standard pitches.

The hob is simply a worm with cutting edges, which, when tipped to the angle of its spiral in the outline of its plan, becomes practically a rack moving in a lateral direction.

Fig. 8 illustrates the diagonal setting of a hob in cutting spur gears. The rotating hob is fed across the face of the blank mounted so as to rotate on its axis in a fixed position, the operation being coincident with that of actuating a gear mounted on a fixed axis by an advancing rack—the basic principle of gear generation.

If the work travels while rotating, and the hob remains in one position, the operation is equivalent to rolling a gear over a stationary rack, the principle employed in producing the shaper pinion cutter.

Among the advantages claimed for the system is that the hob is more rapid in action, due to its multiple-cutting edges operating simultaneously with greater or lesser effectiveness.

Disregarding the relative speeds of milling and shaping operations, the productivity of multiple-cutting edge tools is dependent upon the cutting arc of contact between the work and the tool.

In the case of the gear-shaper pinion cutter the curvature of the paths of the work and the tool, when machining an external gear, are opposed, hence the arc of cutting contact is dependent upon the ratio of diameters of the cutter and gear blank.

In the hob, the pitch line of the hob being straight, the arc of cutting contact is only affected by the diameter of the gear blank, and is consequently considerably greater.

It is fairly obvious that, with such an increased cutting contact, the continuous cutting capacity, together with the elimination of the idle strokes of the gear shaper pinion, the relative productivity of the hob is greatest.

The diagram at fig. 9 illustrates the difference between the arcs of cutting contact when cutting a twenty-tooth gear with a twelve-tooth gear-shaper cutter, and by the hobbing process, the superiority of the hobbing method in relation to arc of cutting contact being clearly shown.

Assuming the face of the gear being generated, or the total width of a number of gears being cut, is 6in., the speed of the hob 150 revolutions per minute, and the diameter 4½in., the hob cutting speed would be approximately 175ft. per minute.

These are average figures for cutting the twenty-tooth gear illustrated, which may also be said of the pinion shaper-cutter, whose stroke is about 150 per minute, and whose effective cutting speed during reciprocation is about 75ft. per minute.

With a cutting arc 65% greater, and a cutting speed 2⅓ times that of the pinion cutter, it is apparent that the productivity of the hobbing process is very much greater.

The chief objection to the hobbing process is that the action of the hob is not perfect, and the teeth profiles produced by it are consequently not so accurate as those produced by the planing-generating processes.

The cause of this lies firstly in the slight difference of the section taken in the axis of the worm, and of that in the axis at which it is set, a matter of from about 3 deg. to 5 deg.

Though the angle at which the hob is set varies very little, it suffices, when the tooth section is imparted to the hob, parallel with its axis, to leave the teeth slightly thick on the points. To avoid this, some hobs have the tooth-flanks made slightly hollow, and others have their points well rounded, while in some instances the tooth shape is taken normal to the direction of the thread.

Then again there is the action of the hob in slipping from tooth to tooth, the blank itself continuously revolving, which produces facets on the teeth of minute dimensions.

If one could conceive the hob as a continuous spiral, without any teeth, but still capable of acting as a cutter, the resulting gear would then be perfect to the same degree as the hob.

It is therefore desirable to get as large a number of cutting teeth as practicable in the hob.

It was previously stated that the hob was tilted over, or set at an angle with the blank, so that the cutting teeth were parallel with the blank; the cutting facets of the teeth, however, are a spiral, therefore it is an impossibility to set the teeth absolutely square.

The teeth of the hob, being actually at a slight angle, cut a space slightly less in width than themselves, the effect on the gear being to leave the points of the teeth over size, as stated.

Some of the advantages claimed for the hobbing process will now be dealt with. The flanks of the teeth, even in small gears, are not formed by radial prolongation of the regular profiles, but are correctly undercut, so that the interference consequent upon the relative paths of the tooth corners reaching behind the flanks is eliminated.

Also that undercutting can be avoided in any case by simply

not allowing the cutter to enter deeper in the blank than to the parallel of the cutter axis, that is, by retaining the standard depths by increasing the addendum of the pinion teeth and the dedendum of the wheel, and simultaneously decreasing the dedendum of the pinion and the addendum of the wheel.

Aside from the fact that this method is possible only when the number of the teeth of the wheel is at least fifty in the $14\frac{1}{2}$-deg. system, there are a number of fundamental defects forbidding its general use.

Mention may be made of the fact that by shifting the outside circles the pitch line of the cutter can no longer come in contact with the pitch circle of the gear to be cut—that, therefore, a line further in or out must take the place of the pitch line.

For this, however, the angle of the hob thread is different from the one of the real pitch line, in consequence of which the threads of the hob set according to the mean angle of spiral lie somewhat at an angle to the direction of the tooth, and, therefore, must cut away more material than necessary and generate profiles of distorted form.

If, on the other hand, the hob be set to the actual spiral angle of the pitch line, it would cut a different pitch from that intended.

These several modifications or corrections are, therefore, inadmissible, not only on account of the distorted profiles produced, but because the generating profile of the worm-shaped cutter does not correctly correspond with the involute rack profile, such defects being increasingly evident as the teeth of the gears decrease in number.

There is another feature of the hobbing process which is worthy of attention. The teeth all being cut simultaneously, there is less liability to distortion, owing to the heat being evenly distributed over the whole blank, and not localised, as is the case with milling cutters or other methods where one tooth only is produced at a time. Also the initial stresses in the blank often cause distortion after cutting.

The crucial point of the whole system is the hob itself, for much greater defects than those enumerated are due to the unavoidable changes in hardening in the production of the hob. The warping of the cutters in hardening causes changes in its individual teeth, both in respect to lead and concentricity. Unfortunately, there is, as is well known, no absolute remedy against this warping in hardening.

Recapitulation.

From the facts outlined, the chief points which present themselves in reference to cutting methods are as follows :—

Series Cutter Method.

1. Nearly all ordinary gears are produced with a compara-

tively small number of cutters. The method therefore furnishes relatively cheap manufacture.

2. Owing to the simplicity of the system, an economical rate of production is assured.

3. Uniformity of output is not assured, by reason of the fact that teeth of accurate proportions cannot be produced by this process, because teeth are accurate only if the number in the gear is that for which the cutter was designed.

4. Gears having a small number of teeth cannot be produced satisfactorily.

Considering these reasons, the conclusion is drawn that the series milling cutter method is not equal to the requirements of automotive and other high-class work where gears are relatively small and have high peripheral speeds and heavy duty imposed upon them.

The Hobbing Generating Method.

1. With a single cutter all gears of similar pitch can be cut—it is, therefore, a relatively cheap tool.

2. Tooth profiles so produced are not true involutes or interchangeable, due to difficulties in manufacture of the hob and in the production of facets on teeth.

3. In regard to tooth form, this method is probably not equal to the forming-cutter method.

4. Corrections to avoid undercutting cause defects in profile and contact, and their application is equivalent to abandoning accuracy.

5. Gears can be produced by this method at a more economical rate than by any other.

Considering these reasons, the hobbing generating system does not meet the requirements of high-class gearing, where silence of action is nearly as great a factor as efficiency. Efficiency and consequent silence of action can only be obtained in gears whose profiles are correct theoretically and practically.

The Planing and Shaping Generating Systems.

1. These methods can be made to produce mathematically correct profiles, because the generated profiles follow the precepts of the laws of gearing.

2. Uniformity of output is assured for the previous reason, even in small gears.

3. The productivity of these systems is not so economical as the hobbing process in certain circumstances.

4. Gears can be produced by the shaper method impossible by any other.

From these considerations it appears that the planing and generating systems only are capable of producing gears accurate and uniform in shape to meet the requirements of high-speed and high-class mechanisms.

Conclusions.

It is the writer's opinion that the 14½-deg. system is entirely unsuitable for use in gearing for high-class work, as being theoretically incorrect for small gears.

That, therefore, it cannot be expected to produce accurate gears of this type by any method of manufacture.

Hence, before attempting to manufacture gears having small numbers of teeth intended for heavy duty, a bigger angle of pressure, together with shorter teeth, should be adopted, or at least a type wherein sliding conditions and resulting efficiency have greater consideration.

Also the shaper-generating system, being the chief one to satisfy necessary conditions, renders it advisable that manufacturers requiring high-class gears should have their gears cut by specialists having such machines, rather than cut inaccurate gear teeth by other inferior means at their disposal.

Finally, the writer believes there is considerable scope for improvement in regard to the rate of production by the shaper-generating method, and that finality in manufacture may be attained in the future by finishing the teeth of gears by grinding, as in the grinding-generating process used in producing cutters. Such a system is adopted in the Maag machine (fig. 10).

The problem in grinding is to substitute for the rack cutter a grinding wheel that shall move in a true plane parallel to the gear wheel axis, such plane to include the profile of the rack-tooth flank.

Also it is obvious that some arrangement is necessary to provide for the wear of the grinding wheel. In this machine the grinding wheels are seen at A, each being driven by an independent electric motor, and arranged near the upper edge of each wheel is a pivoted arm carrying flat ground diamonds, B, on pivoted arms. Every six seconds or so the diamonds are advanced to the edges of the rotating grinding wheels. If the wheel is unworn, the diamond touches the wheel and is held up at this point. If, however, the wheel has worn, the diamond must advance further to touch the edge of the wheel, and in doing so an electrical contact is made, and the wheels are fed outwards a predetermined minute amount—about $\frac{1}{1000}$ of a millimetre—and the wheels are thus kept to the required plane with this degree of accuracy.

If gear grinding is developed as an absolutely commercial proposition, then the hobbing method of gear cutting might again become preferable to other methods by reason of its rapid and economical production possibilities.

THE DISCUSSION.

At the conclusion of the reading of the paper, some slides of gears made by the Power Plant Co. were exhibited.

Mr. J. D. Scaife asked what was the tensile strength of the steel used in these?

Mr. Sykes (Power Plant Co.), replied that the high-speed pinion was of nickel steel, and had a tensile of 60 to 68 tons. The gears were of about 0.5 carbon steel, which was about 48 tons tensile. The pinion would be heat-treated before cutting, but the wheels were not heat-treated. The low-speed gear wheel at the bottom of the illustration was 0.4 carbon, which was about 42 tons tensile. The gears were for transmitting 2,500 h.p., the pinion having a speed of 3,600 r.p.m.

Another slide showed the Sykes gear shaper, the principle being similar to that of the Fellows machine. The particular cutter shown, explained Mr. Sykes, was rather antiquated, as they were now made with a 3in. bore, whereas the one displayed was only 1¼in. bore. The author had spoken of "pitch lines of teeth," "undercut" and "interference." These cutters obviously represented an involute tooth, and all the tooth curve was above the base angle, so that it was a purely involute tooth. Also, he (Mr. Sykes) could not possibly regard that cutter as having any definite pitch circle, unless the pitch and the number of teeth were defined. The cutter was called a 5 P., but it would cut other pitches within certain limits.

Mr. J. D. Scaife said it was now a good many years since he went into the question of the shapes of teeth and interference and so on, which the author had dealt with extremely well. There was one side of the subject, however, which the author might have touched on more fully, and that was the sort of material of which his gears were made. He had seen gears made of various materials and for different purposes, and he believed that in the automobile industry there was a great difference of opinion as to what gears should be made of. Some people used nickel-chrome steel and other mild case-hardening steel, but there was a great deal of difference between the two. In a case-hardening steel there was a hard surface and a fairly soft inside, whereas with a nickel-chrome steel it was hardened through, and was as hard as they could make it. During the war he had had a fair amount of experience with regard to materials for gears used for aero engine work. It was an exceedingly important matter what the gears were made from. They used nickel-chrome steel, and in a machine like an aero engine, where there was a lot of vibration, the gears were not so hard as they should have been. In his case they hardened and tempered down to about 60 tons tensile, and that was why he was so anxious to know from Mr. Sykes what was the tensile strength of the pinions he used. Of course, whilst 60 tons might have been the best for an aero engine, it was not the best for automobile work, and he

would like to know from the author what was the best hardness to fix for a nickel-chrome gear. If the surface hardness of the gear must be as hard as mild steel, then it was necessary, of course, to use mild steel and case-harden it, because they could not use a nickel-chrome steel; it would break off. He wondered if any experiments had been made as to what the surface hardness of a gear ought to be to give the best results in practice. He knew that the A.E.C. of Walthamstow used about 80 tons tensile in their nickel-chrome gears. The gears there were roughed out, hardened, tempered, and cut on a Fellows gear shaper, taking a few thousandths of an inch off to get them accurate. Eighty tons was not glass-hard, and he would like to know why 80 tons had been selected. Would it not be better to go to 100 or more, if the gears could be produced accurately, or did the A.E.C. make their gears at 80 tons tensile so that they could machine them in order to get them accurate? Heat treating a gear distorted it, and therefore it had to be either ground or reground; if the best gear was a glass-hard one, then it had to be soft inside and had to be ground. It seemed to him that the question of the material for gears opened up another story which was rather involved. He was not an expert in gears, but once or twice in his experience he had been faced with the problem of deciding on the right material for gears; and the method adopted really depended upon the hardness which the gears had to be. If they had to be glass-hard, then they must be ground, and any question of gear shaping did not come in. Was 80 tons the best that could be cut on a Fellows gear shaper? He had found the Fellows gear shaper the best for the finishing operation; so much so, that for years he had never studied the question of gear shaping. The machine had settled the question for him. He had found that to be the case for eight or ten years, and he had long since given up the idea of any other machine.

Mr. Sykes said that he was sorry to have to disagree strongly with the majority of the remarks made in the paper. There was a certain amount in it with which he was in agreement, but unfortunately there was a great deal more with which he did not agree. First, he would like to draw attention to the statement made regarding pressure angles. The author stated that even with a 20 degree pressure angle accurate profiles were impossible when the teeth are few in number. He would like to refer to a set of gears which were exhibited at Olympia, in which a one-toothed pinion geared with a 63-tooth wheel. The pinion had a perfectly correct tooth curve, and so had the wheel, and yet the pressure angle was only 20 degrees. Where a mistake was usually made in considering a wheel and a pinion was to say that the gear had a certain pressure angle. It had not. It had a base angle and so many teeth, and nothing more could be said about it. They could only get a pressure angle when there were two gears together, and the pressure angle depended on the distance apart of the centres of the base circle diameters. He was perfectly sure that with gears, where the number of teeth in the pinion, added to the number of teeth in the wheel, amounted to 60 or over, the teeth for the whole working surface could be made purely involute. With less than sixty the teeth can be shortened or, if preferable, the pressure angle can be slightly increased.

There were several limitations, as the author had pointed out, but he was afraid that in making certain remarks in the paper the

author had not taken into considerations those limitations. There were a certain number of broad statements which were likely to lead people astray. He had had a lot of experience with gears, and he had had to design them for a good many years for very high speeds, but he had never found it necessary to design a gear that had any interference or any undercut. He could always manage to make the teeth purely involute, no matter how small the number of teeth might be.

There was a note in the paper that gear-shaper cutters were gashed out by a milling process because the milling process was so much quicker. The Power Plant Co., with which he was connected, made a great number of gear-shaper cutters, and the practice was to gash them on a gear-shaping machine, because the shaper cutter generated its own shape, and because, on the special machines used, which were somewhat heavy compared with the Fellows gear shaper, they could be gashed with a shaping machine in about a quarter the time that they could be milled.

The author had also dealt with the pitch circle of cutters. A gear-shaper cutter was merely a gear, and it had a base circle, but it had not a pitch circle.

The author had dealt at some length with the hobbing process. In his own opinion, the hobbing process was rapidly becoming obsolete, for the reasons stated by the author, and the first reason was that it was very inaccurate. It was simply useless for high-speed gears. One of the author's reasons for rather favouring the hobbing process was the question of production. His own experience, however, was that the gear-shaper process was far superior to the hobbing process for rapidity of work. He had found that wheels could be turned out at the same speed on an 8-ton gear shaper that required a 35-ton hobbing machine. It was perfectly obvious that nobody was going to use a 35-ton machine if they could do the work with an 8-ton machine, and that, he thought, was conclusive proof that the productive capacity of gear-shaping machines was quite as good as that of hobbing machines. A great deal could be said about the basic principle of the hob. The hob was really a helical pinion, but it was because it could not be made a helical pinion with precision that caused it to give such poor results in accuracy. Finally, he thought it inadvisable to describe one particular make of machine in a paper of this nature—although he was guilty of it himself to some extent. There were only two machines mentioned, viz., the Fellows and the Barber-Colman, but in fairness and in justice, if two machines were mentioned like that, the names of the other well-known makes should also have been given. There was, for instance, the Wallwork hobbing machine, the Gleason generators, and many other machines. He himself had no axe to grind in that respect, but he felt it was only fair to mention them all.

Mr. Honer said that he had listened with great respect to the paper because the author had dealt with pressure angles and degrees and so on, but there seemed one particular fact which they as production engineers—and he wished to stress that point—should press home, and that was, the means of producing these gears properly. The author had dealt with various features, but which was the best and the cheapest method? As an Institution of Production Engineers they must bear in mind that they would probably—and he hoped they would—help the manufacturers of this country to decide upon

certain methods of manufacture. That should be their main aim. The question that Mr. Sykes dealt with, as to which was the best machine, was a feature which, perhaps regrettably, would have to be thought out. As an Institution of Production Engineers they could not possibly deal with these problems unless it was on these lines. If one manufacturer put a machine on the market which was not adequate or not up to its work, then it was for them, surely, to condemn it, and he maintained that they should do so without fear. In his own experience, dealing with crown wheels and pinions, his method had been first to gash the teeth out with a set of ordinary milling cutters, and then follow them up on a certain manufacturer's gear shaper; he had found that that was the finest and the best method. He was not going to name the machine, but he had found that process the finest of the lot. He would like the author, if possible that evening, to give a little further information on that point; to deal particularly with the production of gears rather than pressure angles, etc. That was what he claimed to be the main feature of the work of production engineers, that is, to produce the best gear and in the quickest possible time.

MR. BUTLER said his experience of gear work was so limited that he could not say much on the technical side, but he would like to learn something about the methods employed in measuring gears for accuracy. It was all very well to speak of a gear as a pure involute or not, but his experience was that it was a most awkward thing to measure, and, of course, the silence or efficiency of a gear depended upon its accuracy. That was obvious, but there were several little problems in gear making, and there was not enough information as to the special means of measuring accuracy. Therefore, he would like to have something more with regard to that side of the question. Further, such a paper as this should have said a little more about the hardening process. That was responsible for a lot of inaccuracy, and it would have been useful to have been told one or two of the little tricks of the trade to get over that.

MR. GARTSIDE pointed out that in the discussion they should stick to the subject of the paper, which was the production of spur gears. At the same time, in connection with the remarks made by Mr. Sykes, he thought it was a mistake in a paper like this, unless it was possible to cover the whole ground, to mention one or two names and leave out others. It was better not to mention any at all. Might he mention the different systems. Some firms made hobbing machines, some gear shapers of the rotary type, and others, rack tooth shapers. These, he believed, covered the field. There were one or two points which were not quite clear to him. There was the remark about the Bilgram machine, where the author said: "In this manner, the action of the gear working with a true involute rack is reproduced, but the rack has only one operating tooth, and there are no adjacent teeth to obstruct the advancement of the gear, the limitations placed on the involute system by tooth interference are neglected." He could not quite see the point there. It seemed to him that if there were a series of rack-shaped teeth, one would just follow the other, provided it was in correct pitch; it would reproduce the tooth next to it just the same. The action of each individual tooth in a rack tooth cutter was the same, and produced each individual tooth. He might be wrong, but that was the way he looked at it.

With regard to the hobbing machine and the manufacture of hobs, there was a great deal of mathematical data which had to be understood to know really what the action of a hob was, but, as Mr. Sykes explained, it was pretty well understood now that the hob did not produce as accurate a gear as the rotary shaper cutter or the ordinary straight rack cutter. He had never made the comparison himself, but speaking about flats made by the hob, the author mentioned that he had worked out the number of flats down the tooth of an 8-pitch pinion, but had they ever ascertained how many flats there were with a rack-tooth cutter, because there must be a certain number. The movement of the blank at each stroke was almost similar to the hob tooth passing from one tooth to the next in the hob, and there must be a small number of flats even with a wheel cut with a rack-tooth cutter. If they assumed a very quick traverse across the rack tooth, then they would certainly get big flats, but supposing they chopped the tooth out with about four strokes, they would get three or four flats. How did that compare with a hob with a fair number of teeth? He himself had not gone into it, but it was a point that occurred to him whilst listening to the paper.

Some years ago he went into the question of making a hob; in fact, he did make one with which the wheel could be cut without tilting. The original idea was not to get away from any inaccuracies of the hob, but to make a simple machine without having to swivel the head to suit the angle, and he succeeded in making a hob that cut gears with a reasonable accuracy. The difficulty, however—and the reason why the idea was not persevered with—was that if any firm had standard hobs, and they ordered one of these machines, they could not use their standard hobs. That knocked the idea on the head, but he did make a machine, and some of them were still working, and it was rather an interesting process, developing the shape of the hob tooth, and getting the correct thread to cut the wheel accurately, remembering that the hob had not to be tilted. The easiest way to describe it, perhaps, was to say that if one took a hob and held it up in the way that gauges are tested with a lantern, it could be seen whether the hob had a true rack section. He came to the conclusion that it would be possible to have a hob as near correct as it was possible to get it if he generated the thread on the hob in such a manner that it would not need tilting. He mounted the blank in a thread milling machine, and instead of having a milling cutter he had a shaped tool working at right angles to the axis of the hob, and when it had generated the shape of the tooth he just simply cut gashes in and relieved them, and it produced a fairly satisfactory job. He did not do it with an actual steel blank, but with brass castings, so that it would not damage the tool, and then they made gauges to the section and cut the hob, and gashed it out to the gauges. One peculiarity of that hob was, that when the wheel was cut, instead of seeing ordinary flats down the teeth, there was a sort of curved appearance to the cut, which he thought was rather an improvement. However, he never went far enough into the system to see whether it was an advantage or not. That, of course, had more to do with the production of tools than gears, but he thought he would give the information because the discussion on a paper like this led to production in the long run.

THE PRESIDENT asked how many threads this hob had. Was it a uni-thread or not?

MR. GARTSIDE said it was a single thread.

MR. KENWAY, speaking with a little experience of the cutting of gears, said that in his opinion output was not so much a question of the method and of the machine that was used as the problem of the suitability of the cutters. He had always found the hob stood up to high tensile steel much better than the gear shaper cutter, and it was one of the troubles he had experienced in the gear-cutting line to find a method of grinding cutters to stand up to high tensile steel as required, say, in the automobile industry. The question of steels was a very vital one, and a great number of firms engaged in the manufacture of gears for gear-boxes used nickel-chrome steel, but to cut that steel it was necessary to have very keen-edged tools. Gear-shaping tools, by the nature of their manufacture, were ground on the face and had a flat face. There was no rake on the cutting edge on the face, and the cutter that had been illustrated—one of Mr. Sykes's cutters—showed a relief on the face. He himself had tried that method of relieving the face of the cutter, and found that it very much improved the finish obtained with nickel-chrome steels, but the difficulty was the grinding of the relief of that cutter. It would be interesting to have some information of a machine that was on the market for grinding cutters to get the necessary relief. That, in his opinion, was the critical point about the use of gear-shaping cutters in comparison with hobbing cutters, because the inaccuracies generated with nickel-chrome gears were so great owing to the cutters giving out on the gear-shaping machines when the operation was through half way, due to hard spots in nickel-chrome gears. This failure was the cause of more inaccuracies than were obtained with the hobbing process of cutting gears. At any rate, his experience seemed to prove it. He could not say that he had had a very wide and varied experience, but he simply set forth the points, as possibly other engineers might have encountered them.

Whilst he did not stand up for the hobbing machine, because he knew it was going out, if the question of gear grinding came in as a commercial proposition, the hobbing machine would more than hold its own in the future. The advantage of the hobbing machine for making spiral and helical gears was that the angle was definitely determined by the gear ratios. One of the disadvantages of some of the gear-shaping machines was that the angle had to be set to a graduated rule on a circular slide, probably with no vernier reading, and the inaccuracies that could occur were very great. With some types of machine there was a former arrangement which became worn in some one place through continuous use, and when that former was used in another place there was an inaccuracy in the angle, and that was one of the causes of inaccuracy, particularly in single helical gears—*i.e.*, the angle across the face of the tooth not being the same in two gears.

THE PRESIDENT said that he would not touch at any length on the gear-shaping part of the paper. He did not think, however, that the author had expressed himself very clearly on that matter, although he thought he understood what he meant. The author said that an involute gear could not be generated on a Bilgram machine if the pinion size got too small. His own recollection was

that if the pinion shape was correct they could obtain an involute shape with a large pinion, but when they had a small number of teeth there was a certain amount of interference, although there was cut a portion of a true involute. The pinion, however small, would always mesh with its mate cut in the same way. Employed as a lower gear at high speeds and heavy duty, then it was not satisfactory.

The paper dealt with the production of gears, which was a very wide subject. The author did not say to which gears he was referring, but if he was dealing with gears in general, when they came to very accurate high-duty wheels, with that liberal interpretation of the scope of the paper, then they would be more or less in agreement with what he said. Some of the speakers had mentioned the strengths of the steel used and the degree of hardness necessary. That also covered a very wide field, but his own experience of very high duty gears for motor-cars was that he had never yet had a gear fail through want of strength. It had always failed from being overloaded on its pressure surfaces. It was very seldom that a tooth was stripped clean out of a gear, but teeth did wear out when overloaded. Of course, the harder one could get the skin of the tooth, the greater the pressure that could be used between the driver and the driven wheel.

He also thought it was a pity the author did not mention the different types of gear-cutting machines—as types—and if that omission were remedied the paper would be interesting. There was the Gould & Eberhardt and the Barber-Colman, which was a type of hobbing machine; the Fellows gear-shaper was another. The paper should also have mentioned the Sykes gear generator as being yet another type. That, with the Bilgram, fairly covered the ground.

With regard to what the author had said on the hobbing process, that again was relative. If the gears were to be used for low duty, no doubt hobbing was a very satisfactory way of producing them, but when they came to gears which had a collective number of teeth between driver and driven below 60, or below 50, then if the gears were for high duty and ran at very high speeds, totally different methods had to be employed. The method that he had adopted fairly successfully in producing these gears was to gash them in hobbing machines and finish them in a shaping machine. A 3 per cent. nickel steel was used which was carbonised and hardened. By this means he got very good results indeed, and was able to produce gears in that way which were far better than the housing in which they were mounted. The noise which was emitted was not due to incorrectly formed teeth, but was entirely due to faulty housing. It was no use making a gear scientifically accurate to transmit the power if the housing allowed it to spring, making five times as much error as was possible in the shape of the tooth. He had found in his experience—certainly in automobile work—that gear noise on high-duty gears was more often due to want of sufficient strength in the shafts and bearings of the gear-box than to inaccuracies in the shape of the tooth.

There was one statement in the paper he would like to correct with regard to the use of the long addendum in the pinion tooth. He had found it extremely useful, especially when dealing with existing designs. If they had a small pinion gearing into a larger wheel, it was possible to keep the pressure angle lower by using a

long addendum on the pinion and having a short addendum on the wheel. The effect of that was to keep the contact between two teeth over a larger gear ratio without bringing a greater duty on the housings; and if, as he had suggested, there was trouble because the housings were not sprung enough, if they corrected the fault by bringing more duty upon them, they would only make matters worse. He made a gear for a particular type of back axle—it was certainly a bevel gear—about $3\frac{1}{2}$ to 1 reduction, but it was pretty hopeless. He was using a $14\frac{1}{2}$ deg. pressure angle, an ordinary B. & S. shape involute tooth generated on a Bilgram type machine, but the noise the gear emitted was too great to make it useful. Increasing the pressure angle did not help, but by going back to the $14\frac{1}{2}$ deg. pressure angle and using a long addendum tooth, the gear was quite passable under ordinary manufacturing conditions. He believed the author said that the pitch circles did not run truly when that was done, but of course they did. Perhaps he misheard the author on that point.

It was a pity, too, that the paper did not deal with the relative speeds of machining these gears. So far as works production was concerned, if they took an accurate gear for high-duty work, he thought there was no question that the shaping method was the one which would find most favour. If it were decided to shape gears, then the machine that would shape them best was, naturally, the best for the work. If they took a Sykes machine, where they got the two heads on the same machine working on the same wheel, that was about the most rapid method, and he had seen some astounding performances on that type of machine. But hobbing, where the gears were not for high duty or did not run at high speeds, would be pretty hard to beat by any other method of production.

Mr. Hales said he wanted to get hold of the production side of gearing. In the first place, in tackling the problem of the relative speed at which a gear could be produced, either by the hobbing process or by the shaping process, it was first necessary to determine exactly what type of machine they were using, and for what purpose; whether it was a cast-iron gear for one definite purpose or a steel gear for another definite purpose. It all depended on the duty for which it was to be used. He would like to have had some figures set forth in the paper relating to the relative speed at which gears could be produced on the different machines, always starting from a fixed basis, say 60 tons tensile. Of course, they had to consider the requisite accuracy of the gear. Then he would like to see figures setting out the time in which gears had been produced.

There was another important factor in deciding what machine was the most efficient. From the production point of view, if they took a machine that cost, say, £1,000, as against a machine that cost £500, it would be ridiculous to compare the two machines from the point of view of speed. It was not only the speed that had to be taken into account, but the most economical way as a whole in which the gear could be produced. They had to consider, first of all, the size of the machine, the h.p. absorbed, and also, of course, capital outlay, floor space, and so on. These were all important items. Then, again, there were the tools—the relative cost of hobs as against shaping tools. He would like to see some figures of cost in this connection, because, after all, what was wanted was

economical production, given a standard of accuracy in the first place, rather than the comparative speed by itself. If the author could give some little help in that direction, it would assist the production engineer very considerably.

Mr. Waring-Brown, replying to the discussion, said that most of the criticism of the speakers could be reconciled with what he had said. On the question of steels, he could not possibly go into that in a paper of this kind, because the variations in steel were so enormous. Practically every firm used a particular steel with which they had had experience and which they liked. It would, however, be a good idea to have a paper on the subject. He quite agreed with the President that a gear seldom failed through lack of strength, but that failures were due to the mountings.

Mr. Scaife said he had had a lot of gears fail, and at one time it was a very serious matter with him.

Mr. Waring-Brown agreed that they had failed, but in designing gears now a very large factor of safety was adopted which, at any rate, wore out the bearings. One of the big troubles was due not so much to overloading the bearings as to there being a great deal in the question of erosion. He did not know whether they were aware of it, but that was a point which had been very largely brought out by Mr. Lanchester recently in regard to gears. In designing a pair of gears which should be absolutely accurate, it was arranged that the forms of the teeth would give, as far as possible, a rolling action, and not a sliding action, because sliding meant friction and inefficiency. Erosion was caused by there being such a good rolling contact with the oil. The whole of the lubrication was squeezed out just at the point of rolling contact, and the friction really became very bad, and formed a slight groove in the face of the tooth all along. Mr. Lanchester and others had proved that the erosion set up had been so bad as to necessitate the gears being replaced.

Regarding the pressure angle, he quite agreed with what Mr. Sykes said about that and the base circle. As a matter of fact, he believed that what Mr. Sykes stated was the basis of the Maag gear, which varied the pressure angle and the base angle to suit any particular individual ratio. That brought up the question of long addendum and short addendum. They could be cut, they looked nice and seemed to roll nicely, but if one set them out to a large scale it would be found that the sliding and the rolling conditions were not so good as they ought to be.

For example, if one took a gear which was correct, on examination in action it would be found that there was a little rolling and a little sliding, and the objective was to develop a tooth so that the relative sliding and rolling were counterbalanced. As a matter of fact, in some cases of long and short addendum gears there would be found a little pure rolling, and then probably a lot of sliding—a little more rolling, and then a lot of sliding, so that in making long and short addendum gears, although they appeared to roll nicely, the sliding and rolling conditions of the tooth form resulted in noise and inefficiency.

Mr. Sykes asked how many rolling forces the author got on a tooth? He had spoken of a little bit here and a little bit there.

Mr. Waring-Brown replied that it was according to the shape of the tooth. Usually it was five.

MR. SYKES said he should imagine there would never be any rolling except on the pitch line. All the other was rubbing or sliding.

MR. WARING-BROWN said the further they were from the pitch line the more sliding there would be.

MR. SYKES said that simply determined the speed of sliding. There was no rolling; it was all sliding, so that they had to talk about the relative speed of sliding, and if the gear was lubricated well it would wear well.

MR. WARING-BROWN :—And be less efficient. Continuing, Mr. Waring-Brown said that the cutter he referred to in the paper was the Fellows; of course, Mr. Sykes's cutter might be much better.

With regard to the speed of production, he would like to say that he had had very little time to prepare the paper, but he had intended to put in some relative productivity data and some costs, but, unfortunately, the time at his disposal did not allow him to do so. Also, in mentioning the Fellows, the Bilgram, and the Barber-Colman machines, he did not mean to place them forward in any other way than that they were the pioneers. The Barber-Colman happened to be the machine with which he had had to deal, but he was absolutely unbiased with regard to any particular machine.

As to methods of measuring accuracy, that again would form a very good subject for another paper, because there were a large number of different machines for measuring inaccuracies of sizes and so on.

He agreed that the hobbing machine stood up better than any other type, but what he was aiming at in the paper was to get the best gear for the gear-box of a motor-car, and that the cost of obtaining it did not matter so long as they got the best. At the same time, he did not really think that hobbing met the occasion. There was a certain amount of distortion in the hardening, and someone came along and said the hob could be ground by a generating process. His own contention, however, was that one need not grind the hob at all. He was speaking mostly of hardened gears, and from that point of view he thought the hobbing process would show the largest productivity, and would do all that was required, if they generated the teeth by grinding.

THE PRESIDENT said he was not able to announce the date of the next meeting, as Mr. Hammond, who was to have read a paper, was not able to do so. Therefore the date of the meeting and the title of the paper would be announced later. In the meantime, the Council had decided to change the day of the meetings from Saturdays to Fridays, at any rate temporarily, as there had been many protests against the Saturday meetings. There were a large number of members who were anxious to come, but they felt they could spend their Saturdays evenings more congenially. Perhaps when the change was made, they would have larger attendances.

On the suggestion of Mr. Scaife, the feeling of those present with regard to holding the meetings on Fridays was taken, and there was an overwhelming response in favour.

A hearty vote of thanks to Mr. Waring-Brown concluded the proceedings.

COMMUNICATIONS.

We have been interested in reading the report of the discussion on Mr. R. Waring-Brown's paper on "The Production of Spur Gears" in *Engineering Production*.

We note that Mr. Honer advocated that the Institution should frankly and outspokenly condemn any machine put on the market not up to its work.

It occurs to us that if this suggestion is acted on—and some are blessed whilst others are cursed—there will be lively times in store.

At any rate, we hope you will pardon us if we suggest that, without limiting or restricting free and reasonable discussion, the published proceedings of the Institution should not be allowed to be exploited for advertising purposes.

We have no particular axe to grind in this matter, but we are somewhat surprised that the discussion did not reveal a fuller knowledge of the Sunderland system of gear cutting and the Sunderland gear planers we make. Perhaps we have not made a great splash in advertising these, but that they are doing satisfactory work is, we think, abundantly proved by the fifty testimonials reproduced in our Publication AA.3, copies of which we shall be pleased to forward to those interested.

J. PARKINSON & SON.

Shipley, Yorks.

We have followed Mr. Waring-Brown's paper on "Gear Production" with more than ordinary interest, and the fact that we cannot find ourselves altogether in agreement with him on certain points by no means prevents our admiring the manner in which he has handled so intricate a subject as gearing.

Also, we were particularly interested in the controversy which this gentleman's remarks naturally raised, though we can hardly give credence to the fact that certain parties actually deny to hobbing the premier place as the fastest known method of commercial gear cutting. In confirmation, one has only to turn to the mass of present-day figures, which, so far as output goes, place hobbing in a position on its own, and also to the fact that the great majority of the American "big producers" rely upon hobbing to meet their high demands.

In no other system is there a total elimination of lost motion as in the hobbing process. Whereas in this latter method the cutter is always removing metal, in all other processes there are two, and sometimes three, motions made for one which actually removes any metal. Also, hobbing has a very great advantage in this respect, inasmuch as by using multiple-start hobs the output can be doubled, or even trebled.

In no other method is it possible by the mere redesigning of the

cutter to get such greatly increased results; of course, in some machines two cutters can be employed, but this is also possible with the hobbing machine. In such cases, however, these machines are really two machines in one, and have a corresponding cost and take up a corresponding amount of floor-space.

The statement made to the effect that the hobbing process, if anything, was dying out appears to show a lack of vital practical information regarding this aspect of the subject. As a matter of fact, the "boom" period with its cry for "high production" gave a big impetus to hobbing machine manufacture, as any maker can readily testify.

We do not say that advocates of other systems did not get similar results, but certainly it is quite erroneous to say that hobbing is by any means less popular than formerly.

Actually, this method is now taking its right place in relation to other processes due to the fact that the question of hob manufacture has been satisfactorily settled.

At one time the hobbing process was under a very great disadvantage, because it was difficult to manufacture hobs which could be relied upon as correct, and anyone who cares to glance for a moment at the formation of a hob will readily appreciate the difficulties with which the manufacturer was confronted. Now, however, all such difficulties are definitely overcome by the fact that hobs can be ground true to form after hardening, and are, in fact, being supplied regularly as a commercial proposition.

Prior to the advent of the ground hob it could not be refuted that the ordinary formed hob was the weak link in a high productive system, but now that a ground hob can be secured there is a great future for the hobbing process, which is, without doubt, the fastest possible way of producing spur, or even spiral, gears.

BARBER & COLMAN, LTD.

Brooklands, Manchester.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting was held at the Institution of Mechanical Engineers, London, on Friday, November 25th, Mr. Max R. Lawrence, President, being in the chair.

The minutes of the previous meeting were read and confirmed, and the Hon. Secretary announced the names of new members elected since the previous meeting.

The President then called on Mr. A. F. Guyler to read his paper on "Drawings and Production," which was followed by a live and interesting discussion.

At the close of the meeting the President remarked upon the particularly good attendance, and suggested that the Council's decision to hold meetings on Friday nights instead of Saturdays was obviously fully justified.

Votes of thanks to the author and to the Institution of Mechanical Engineers for the loan of the Lecture Hall concluded the proceedings.

DRAWINGS AND PRODUCTION.

By ALBT. F. GUYLER, M.I.P.E.

In this paper, "drawing" is taken to refer to any representation of an article by means of lines, with or without notes, in order to convey or record the idea of form and size of the article, and this would include any copy or reproduction if this serve the same purpose as an original.

By production is understood the flow of work from the inception to the completion of the article.

Drawings range from a rough sketch with chalk or pencil to arrangement drawings showing every detail of a machine, and few articles are made without a drawing of some description.

As a rule, a drawing is the simplest method of conveying or recording particulars of any article and the one most readily understood. Descriptions of even common mechanical elements sound strange. Suppose, for instance, that an article is given as having a cylindrical portion $\frac{3}{4}$in. diameter by 1in. long, along which a helical groove is cut, the section of the groove being a 55° vee with a radius of $\frac{1}{64}$in. at the top and bottom, and the ridges $\frac{1}{10}$ in. apart, and that at one end of the cylinder is a hexagon portion $\frac{5}{8}$in. thick and $1\frac{5}{16}$in. across the flats of the hexagon, such an article would not be easily recognised as a $\frac{3}{4}$ Whitworth hexagon head screw 1in. long, yet a drawing of this would be understood at a glance.

When an article is to be made by a person other than the designer the best alternative to a drawing is a sample or model, but samples are not always available, and in any case are only possible for small and medium-sized objects, while it is obviously impossible to supply a sample of a thing not in existence or of which only one is required. A further disadvantage of the sample is that it makes no allowance for variations in manufacture, leaving the matter of fits and clearances to the one making the new piece.

Drawings exert an influence on production at all stages, from the selection of the material to the assembling of the parts and the final inspection. Indeed, the influence commences before the production itself, in that it is often decided from the drawing whether the article shall be made at all, and, if so, in what quantities, in what time, the number, kind, and sequence of

operations, the plant and tools required, and the approximate price, while the drawings also accompany the finished article to explain its method of installation, its uses and operation, and the form and description of its parts for replacement.

The design of an article frequently decides whether it can be produced economically, and the final shape adopted is usually decided at the time the drawings are made. But although manufacturing considerations should be taken into account at this stage, the use to which the article is to be put, its appearance when finished, amount of wear after long use, or even climatic conditions or personal opinions, may make necessary a construction which is anything but desirable as a manufacturing proposition.

Production can be held up in the beginning by lack of instructions or by instructions being issued in the wrong order, as, for example, when drawings for parts easily obtainable and not required until the final assembling of the machine, are issued before those for patterns, forgings, and parts needed at the commencement of assembling, and which require considerable time to obtain or produce. The first consideration, therefore, after the design is decided is to get the drawings forward as soon as possible and in the order best calculated to have the components completed in the sequence in which they will be called for in assembling.

Changes in design are sometimes found desirable or necessary during detailing—changes which are not apparent until this stage is reached—so that it is well to get the last drawing finished as soon as possible after the first is issued, so that the first-made parts have not advanced too far in the event of any modification having to be made.

The actual drawings of the parts themselves cannot be proceeded with until the design is approved, but a rough draft of the number of parts required and their arrangement can frequently be made and the sheets prepared for the drawings.

It is desirable that all drawings be made to a small number of standard sizes, and that proper filing and recording facilities be provided for the drawings. This makes it possible to cut the paper and tracing cloth to size without waste and to rule up the sheets beforehand or to purchase them ready printed with standard ruling and title space. This saves time in the office and gives more uniform results, while if the sides of the larger sheets be multiples of the smallest the prints may be folded to one size for filing, making reference to them a simple matter.

The actual sizes used will, of course, depend to a large extent on the size of the article being manufactured, as it is obvious that sheets of the same size would not be suitable for, say, watch or typewriter parts and the components of machine tools. In each case, however, the same number of variations would prob-

ably be sufficient, although the largest size in the one case would perhaps be the same as the smallest in the other.

Certain information, such as the scale, drawing number, title, material, pattern number, finish, signatures of draughtsman, tracer and checker, and record of changes, is required on every drawing. A proper space should be provided for these in the heading of the drawing, as this information is not so easily overlooked when a place is provided, and it can be readily found without having to search over the whole sheet.

It is also convenient if the heading be so arranged on the

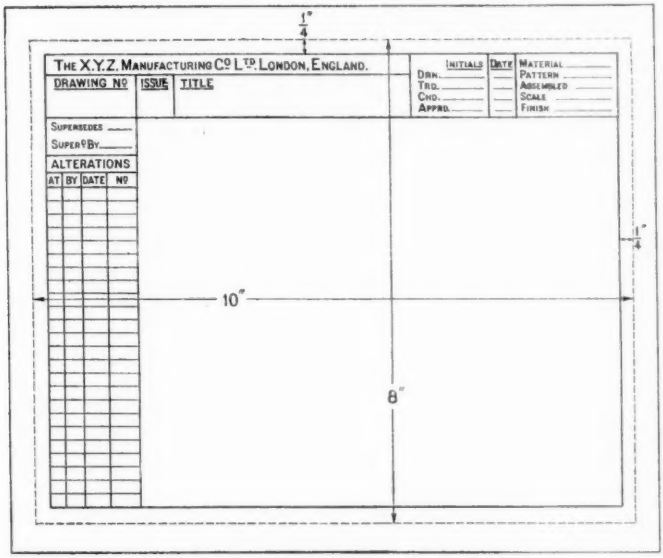


Fig. 1.—Standard minimum size sheet.

sheet that it always appears in the same position on a print folded to the smallest size and so that when the prints are filed away the drawing number is the right way up and can be seen without removing the print from the file. Thus, if the smallest sheet is 10in. by 8in., and the heading occupies the 10in. side, as in fig. 1, when using the larger sizes the heading would still be the same size and would be situated along one of the sides the length of which is a multiple of 10. The 10 by 16 size would appear as in fig. 2, the 20 by 16 as in fig. 3, the upper part of which would also give the 20 by 8 size, and so on. The sizes refer to the drawing sheet sizes, and not to the border lines, the

border on the larger sheets being slightly wider than on the smaller sheets, so that when printed and trimmed to give a border the width of the smaller sheets, the portion folded behind the headed 8 by 10 part will not protrude.

In making drawings, anything which tends to make confusion should be eliminated as, whenever there is a doubt as to the exact requirements, delay is certain to be caused, with the probability of scrapped parts and unbalanced production. It is well, therefore, to keep the arrangement of the drawings similar in each case.

In the first place, the position of the views in relation to each other should be constant, as there is nothing more confusing

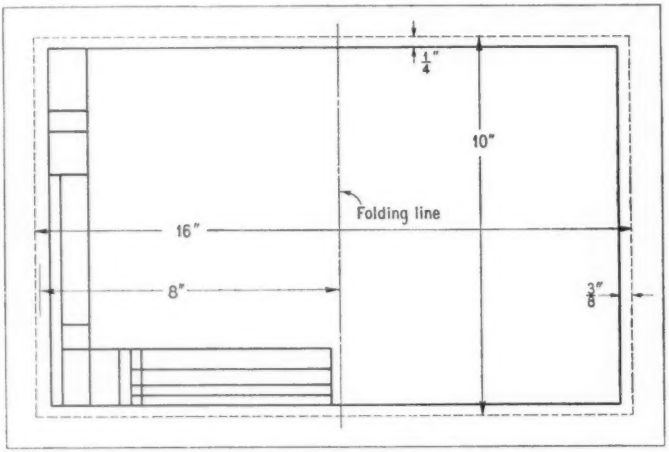


Fig. 2.—Sample sheet of multiple dimensions.

than to have part of the drawings made with English, and part with American projection; errors are frequent through assuming the wrong projection, while in some cases it is impossible to tell from the drawing which projection has been used.

Particular care should be taken in this respect with drawings of parts which are to be purchased out. It is as well to indicate on these drawings, by a note or arrows, the direction of the views, as the supplier probably does not use the same projection on his own drawings, and confusion is thereby avoided. Another point with respect to "purchasing" drawings is that such drawings sent out for quotation should be distinctly marked, "For Quotation Only," and the drawing accompanying the order with "For Order No. — Only," as any slight modifica-

tion might pass unnoticed, and an old or obsolete drawing be used if such had not been returned to the purchaser.

It is usually convenient to make the elevation of the part show the object standing in the position which it occupies when assembled, as it is more easily recognised this way than when inverted or standing on end. Where the part is so shaped that it is necessary to hold it with any other side than its base downwards during the greater part of the machining operations, it is better to draw it in this position, as the form is thereby more easily compared by the workman performing the operations.

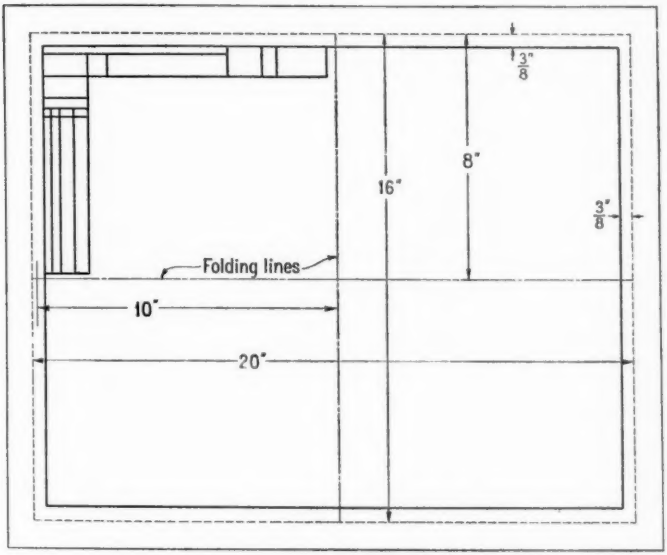


Fig. 3.—Sample sheet of multiple dimensions.

This applies to drawings of parts to be made on turret lathes from bar stock, where the piece should be shown whenever possible with that end to the left hand which is parted from the bar when the piece is complete, as, for example, in fig. 4.

Enough views of the piece should be given to afford a clear idea of the construction, but too many only increase the size of the drawing without adding to its clearness, although in this respect it is often preferable to add another view rather than to indicate important hidden surfaces by dotted lines.

There is sometimes a tendency to make drawings too good—for example, to draw in a thread of correct form and to scale,

to show the teeth of a gear, or a large number of rivets or screw holes which are all of the same size instead of using conventional methods and abbreviations or indicating the centres only and adding a covering note. This excess of zeal does not always make the drawing more difficult to read, but it is liable to delay the issue of the drawings unnecessarily. Of course it is possible to go to the other extreme and use abbreviations which are so unusual that they are not easily recognised, and this should be avoided.

The arrangement of the dimensions on a drawing should be given careful consideration, the dimensions given being those which are to be measured, so that no adding or subtracting is

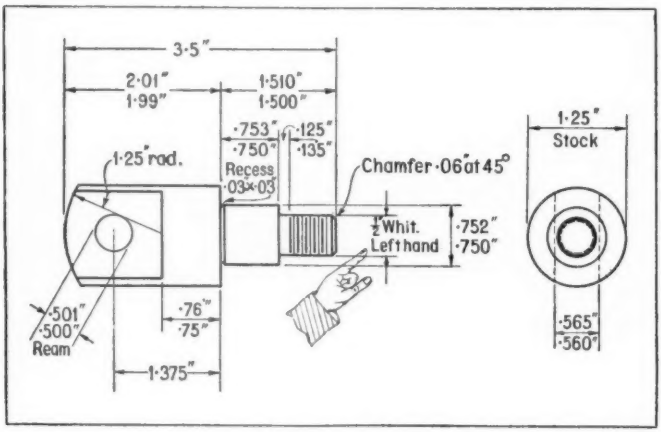


Fig. 4.—Standard drawing of a detail.

necessary by those doing the work. These dimensions should also correspond with those on the gauges when these are supplied so that there can be no misunderstanding. Whenever possible the locating point for the machining should also be the point from which the dimensions are taken, as otherwise the variations of dimension between the locating and measuring points will affect the measured dimension to such an extent that it may not be possible to set the machine and produce work within the limits of variation allowed. When the locating point for machining is not available for use as a measuring point another point should be chosen and all dimensions taken from this point.

When a number of operations are to be performed on a piece it is convenient for the workman if the dimensions be grouped

for each operation so that the ones which he requires are easy to find. This grouping is illustrated in fig. 4, where all the dimensions required on the turret lathe are shown above the centre line with the overall dimensions at the top, all the dimensions for lengths being given from the shoulder, as, the bar being gripped in its length, the locating point for machining is not available for dimensioning. The dimensions for the milling are given approximately in line with each other, and the one is given from the shoulder which is used for location during the operation, the same location and point of measurement being used for the drilling operation.

This figure also illustrates a point in connection with the conventional method of showing a screw-thread; it will be seen

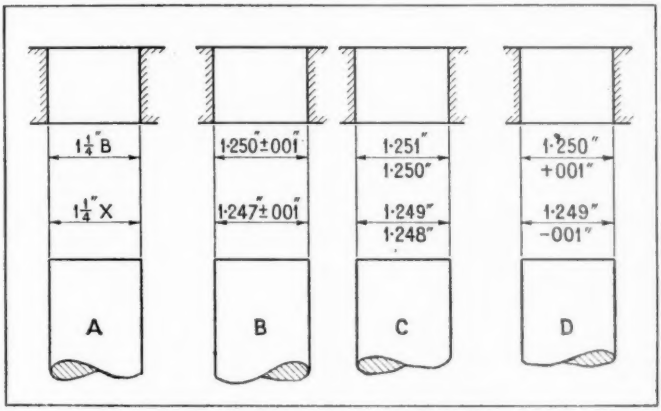


Fig. 5.—Method of denoting tolerances.

that the thick and thin lines representing the thread are square across the piece, instead of being inclined, as is the usual practice. This makes for easier drawing, while at the same time there is not the same possibility of error, when showing a threaded hole in section, of inclining the lines to show the wrong hand thread. Right-hand threads are the more common, and in most cases where no note is made it can be assumed that a right-hand thread is needed, whereas in the event of a left-hand thread being required a note to that effect is added. A hand pointing to an important or unusual note is very useful and can be made quite easily with a rubber stamp, but such signs should not be used too often, or the desired effect is not obtained.

It is good practice to give limits to all dimensions. Dimensions which do not matter are usually the ones to give the most

trouble. A $\frac{1}{4}$in. on the outside of a casting would probably be in the way of nothing—until one tries to get it into a jig—and then production is held up while the jig is spoiled to make room

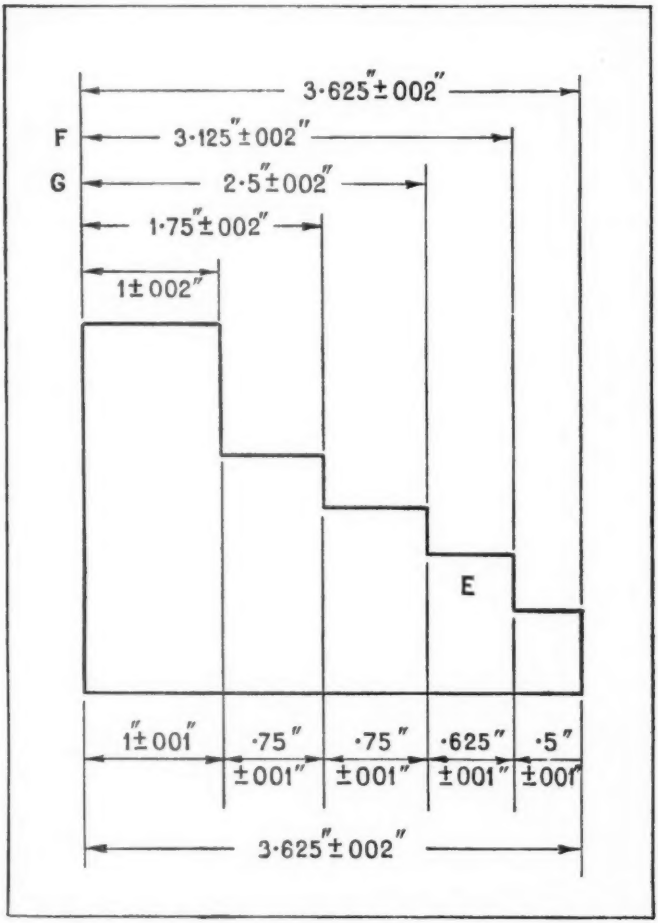


Fig. 6.—Correct and incorrect methods of dimensioning.

for the part, whereas, if the allowable variation be stated in every case, allowance can always be made for parts to clear each other. There are limiting sizes to every piece, and if the variations are

left to the discretion of the workman, who may not know the use to which the part is to be put or the importance of the dimension, he may either make the variation so great that further machining or hand operations are necessary, or he may spend time on machining to size after the part is already sufficiently accurate for the purpose for which it is required.

In fig. 5 four methods of denoting tolerances are shown. The letters B and X at A refer to the Newall standard limits, at B is given the mean dimension with an allowable variation each side, at C the maximum and minimum dimensions are stated, and at D the maximum metal size is given so that the variation from this will increase the clearance between the two parts.

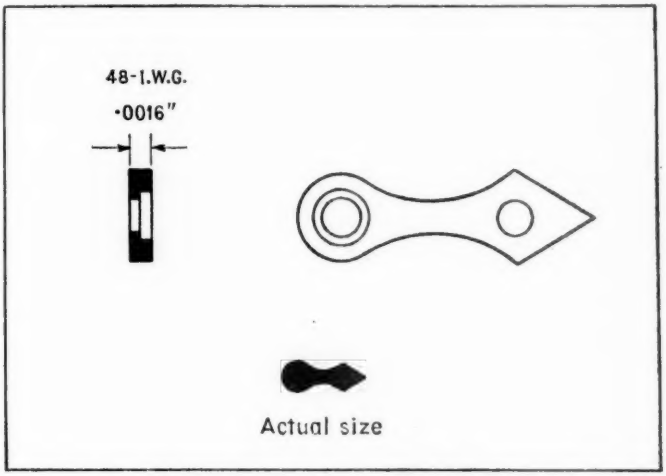


Fig. 7.—Drawing showing detail enlarged.

The method to use may be a matter of personal preference, but whichever is adopted should be adhered to on all drawings.

Whenever the length of a part is required to be within certain limits of a stated dimension and the part is divided into a number of steps, each of which must also be within stated dimensions, all dimensions should be taken from one point so that the allowable variation on one step is not cancelled by the variations of the other steps. For instance, if the lower set of dimensions be taken in fig. 6, it will be seen that it would be impossible to take full advantage of the allowances given on the steps and be certain of keeping within the given overall size, while if the upper set of sizes is used, no such trouble would be encountered. Again, taking advantage of the step sizes,

the 0·5 step could be 0·006 over or under the nominal size, in spite of the small allowance to each step, whereas it would not be possible for the same step to vary more than 0·004 each way with the upper dimensions. If it were necessary for the step E to be within the dimensions given, then this size should be indicated and the dimension F or G omitted.

A drawing should be complete in itself, and should require no explanation, as the same explanation might not be given the second time, or the person possessing the required information might not be available at the time. The information on a

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STANDARD LIST A-248 | ISSUE 4 | TITLE AXLES

Material M.S Finish M/c

Note:- Any change to be made on drawing also.

Supersedes

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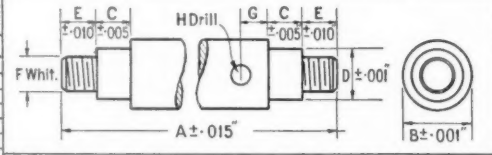
ALTERATIONS

AT	BY	DATE	No
①	R.J.P.	30/10/18	324
②	H.J.	3/5/19	436
③	S.H.	6/6/19	542



No	A	B	C	D	E	F	G	H	Remarks
1	6·5"	·75"	·5"	·50"	·375"	5/16"	·625	1/4"	
2	8·0"	1·00"	·75"	·75"	·625"	1/2"	·75"	1/2"	
3	8·0"	1·25"	1·125"	1·00"	·875"	1/2"	·75"	1/2" ③	
4	②10·0"	1·50"	1·5"	1·00"	·875"	1/2"	·875"	5/16"	
5									
6									
7									
8									

Fig. 8.—Standard list of parts.

drawing should be such that any number of pieces made to the same drawing at different times by the same or different people would each answer the purpose for which it was originally intended. If the information on the drawing were such that the piece required subsequent alteration in order to make it function properly, then the drawing was incorrect or incomplete.

Every drawing should be distinctly marked with the scale used and every out-of-scale dimension underlined, although it should be clearly understood that blue-prints should not be scaled. When two dimensions are so nearly on the same line that one may be taken in mistake for the other, one should be drawn out of scale and the dimension underlined.

When a small object is drawn a number of times full size in order to dimension it clearly, a full-size blacked-in view of the article should be given on the drawing, as in fig. 7, as it is more difficult to realise the size of an object drawn oversize than one drawn to a reduced scale. It is well also in the case of sheet metal and small parts to black-in the sections instead of attempting to draw them to scale with double lines. When a sheet metal, wire-gauge, or drill number is quoted, the decimal size should also be given, as there is usually much confusion with these sizes.

All notes and dimensions should be placed away from the views except the signs for denoting machined and ground surfaces. These latter should not be used when it is obvious that

DRG. Nº A-248	PRINT ISSUE RECORD												STD. LIST AXLES		
ISSUED TO	Nº	DATE	RECD	Nº	DATE	RECD	Nº	DATE	RECD	Nº	DATE	RECD	Nº	DATE	RECD
OFFICE FILE	1	3/10/18	J.J.	2	21/10/18	J.J.	3	4/2/19	S.H.	4	6/6/19	J.J.			
MACHINE SHOP															
PROGRESS DEPT.															
TOOL D-O	1	3/10/18	R.S.	4	7/6/19	R.J.									
INSPECTION DPT.	1	3/10/18	B.H.	3	4/2/19	A.L.	4	7/6/19	A.L.						

Fig. 9.—Record of prints issued.

the face must be machined, as, for instance, in the case where a drilling or threading operation is called for.

When making drawings to show parts assembled it is usually unnecessary to indicate all hidden surfaces, as these sometimes tend to make the drawings too congested, so they may, with advantage, be omitted. Overall dimensions are often useful, however, for checking purposes, even if they are not needed for the actual assembling.

In most works there are a number of parts of similar design, but having different dimensions, and these are frequently entered on what are termed standard lists. Such a list is shown in fig. 8. This type of list is very convenient for drawing office reference, as the corresponding sizes are shown together, and the one required for a new mechanism can be quickly found, or

a new size added without making a new drawing, but for shop use they have several disadvantages. The dimensions being so far away from the illustration, and other dimensions being between, increase the possibility of error and make the drawing more difficult to read, and as the illustration is not to scale for every set of dimensions the appearance of the finished piece may cause further time to be spent in checking over several times to make sure there has been no mistake.

Sometimes this type of drawing is used for drawing-office

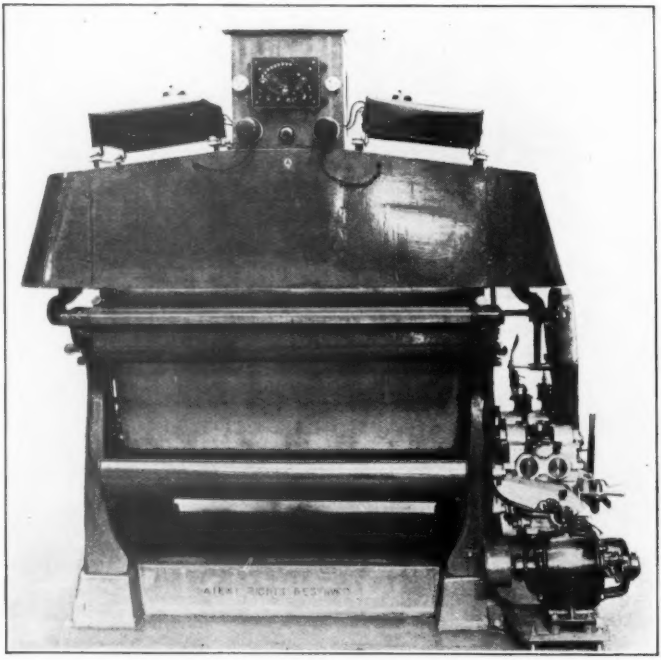


Fig. 10.—Halden continuous blue-printing machine.

reference only, and blue-prints made without dimensions, a white patch being left on the print so that the dimensions can be filled in from the list as required. This introduces the possibility of copying errors, and as it may be necessary to make several copies of the same size piece on different occasions, it is better to make up the separate drawings, even if the list be compiled for drawing-office use. In this case a note should be made on

both the drawings and the list calling attention to the other, so that in the event of a change both are made to agree.

Never omit to have a drawing checked before issue to the works. It is false economy to save by cutting out this operation. A very short delay for this purpose may save considerable time later on. The time required for checking may be reduced and a better check made if a "checking programme" be used giving the order in which the faults should be looked for. If the checker be called away when the drawing has been only half examined, a pencil note of the checking item on the programme

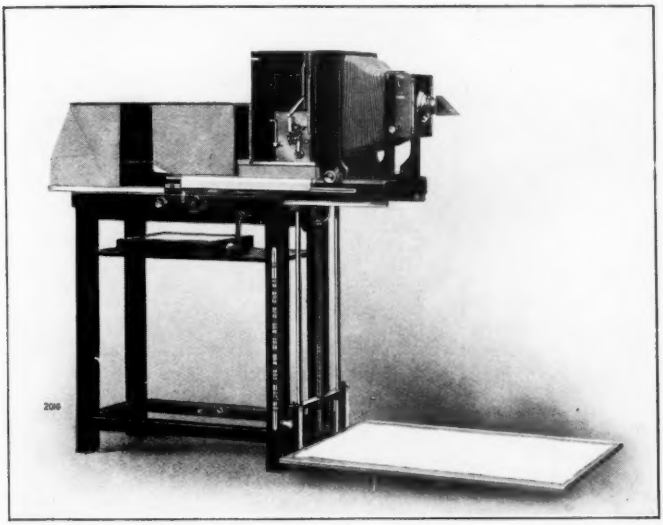


Fig. 11.—The Photostat.

which has been completed will prevent him wasting time or missing any item on his return.

After manufacture has commenced, changes on drawings are often required, due to modifications of design or a number of other reasons. When these are necessary the effect of the changes on other parts, stock, machines already completed, and on tools and fixtures, should be considered. If the change affects other parts these should be changed at the same time and parts in stock corrected. When the alteration is such that it is not possible to use the new piece as a replacement on those machines already made, it is usual to make a new drawing, give it a different number, and keep the old drawing as a record of

parts made so that they can be replaced without trouble. When the drawing is altered, however, a record of the alteration with the reason and date should be kept in a book or on cards for future reference. The position of the alteration should be indicated on the drawing, together with the record number, so that full particulars of the alteration can be obtained at any time. A good method of indicating this position is to place a number in a small circle near the correction, and a corresponding number with the date, signature, and the record number in a column at the edge of the drawing, as shown at the extreme left in fig. 8.

When a change has been made, all copies should be with-

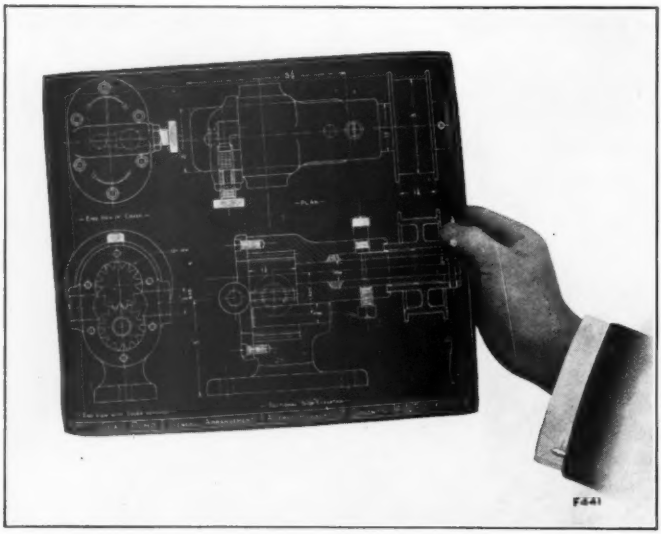


Fig. 12.—Photostat print from drawing.

drawn and altered or destroyed. In order that none of these shall be overlooked, a record of every copy taken should be kept, with the signature of the person to whom each is issued. Such a record is shown in fig. 9. When the print is returned the issue is cancelled by crossing through in red ink, and if a copy be lost or destroyed a note is made to this effect on the record. The number referred to is the issue number which is in the space following the drawing number. This is not entered on the drawing itself, but only on the print, and represents the number of editions of the drawing—that is, one more than the number of changes made on that drawing. If this issue

number is noted on all orders, an obsolete print, which had been lost or not withdrawn for any reason, would not be used for making new parts. All prints issued should be clear and distinct, and when they are to remain in the shop for any length of time they should be mounted on card or sheet metal and varnished.

When only a small number of prints are required they may be made by daylight. The time required for printing will be anything from a few minutes to several hours, according to the light available. It will be apparent, therefore, that when any

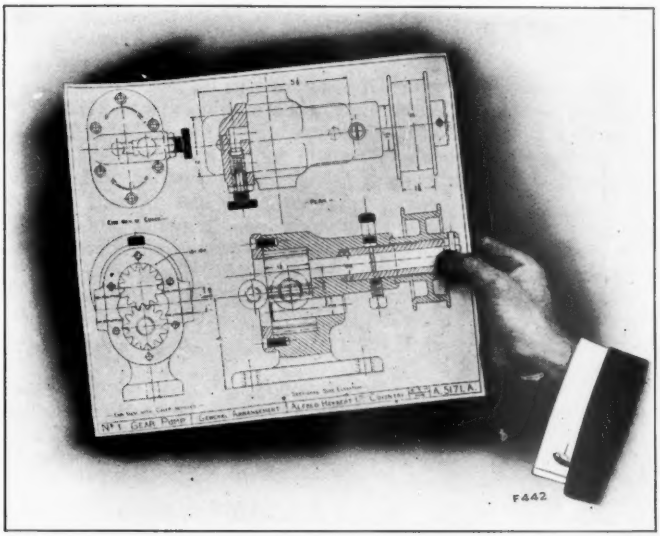


Fig. 13.—Photostat copy of Photostat print shown in fig. 12.

number of prints are required it is better to use artificial light, which gives more uniform results, as the time is constant for any one tracing, and may be easily estimated for any other tracing.

There are a number of excellent machines available. In some of these two large or a number of small prints may be made at the same time, the tracings and printing paper being held against the outside of two bent glass plates by quickly clamped covers, the frame being horizontal while loading. After loading, the frame is turned to the vertical and the exposure made by lowering the arc lamp down the centre. The lowering gear

can be adjusted to the requisite speed for different papers and tracings.

In other machines the printing is continuous. An apparatus by Messrs. J. Halden and Co. shown in fig. 10 will serve to illustrate the type. The tracings and paper are fed into the machine either in one continuous length, or small tracings may follow each other or go in side by side. The length of time required for the tracing to pass through the machine can be regulated so that the correct exposure can be given before it passes out. Machines of this type are also made to take two tracings at the same time, one on each side of the machine.

A washing and drying machine for prints is shown (not illustrated here), the machine taking the roll of exposed paper, passing it through a bath fitted with a water spray, and then through a drying oven, after which it is automatically rolled up. These machines save considerable time when making prints.

Another method of producing copies is by means of the Photostat, the appliance being shown in fig. 11. In this method a photograph of the drawing is taken direct on paper, and, as the light does not need to pass through the original drawing, copies may be taken from drawings made on opaque paper without the expense and time of tracing. Copies may also be made of blueprints and typewritten matter, for example, when single copies are received from other works. These are ready in a few minutes without the possibility of copying errors. By the use of the Photostat the size of the copy can be reduced to make it more convenient for handling.

In fig. 12 is shown a Photostat copy of a drawing, giving white lines on a grey ground, and a copy of the original Photostat print, giving dark grey lines on a white ground, is illustrated in fig. 13.

A fire in a drawing office may cause a long delay, so that if a fireproof room is not available for storing drawings, a good plan is to keep a duplicate set of prints in a part of the works or offices as far away as possible from the drawing office.

Few things can assist production so well as good drawings, but they must be correct, ready when required, easy to read, and give all the requisite information to make the article satisfactory.

THE DISCUSSION.

MR. FAIRBROTHER in opening the discussion said the paper threw a great deal of light on what drawings should be. Production engineers ought to insist on the drawing office amplifying the drawing more, because they wanted something better than they had at the present time. The drawings should be in such a form that workmen going from one shop to another ought not to be in difficulties. At present one firm adopted one method of dimensioning and fixing limits, whilst the practice of another firm would be quite different. This meant that a workman on entering a strange works was not at first able easily to read the drawings. It should be made clear on the drawings exactly how they were to be read, and the dimensions interpreted.

The author had shown several slides in which the description of the drawing was in the top left-hand corner, but he himself thought that was wrong. All drawings ought to be described in the bottom right-hand corner, so that when they were filed the description could be seen without taking out the whole of the drawings. As to process drawings for separate operations, he was absolutely in favour of this, because then no man in the shop could misinterpret them. Furthermore, there should be some system of recording on the drawings, be they main drawings or process drawings, what jigs, tools, and gauges were available for the workman to use, otherwise the foreman, in order to discover this, had to run round the factory. Very often work was commenced, and sometimes finished, without using the jigs which had been specially designed to manufacture certain parts.

The author had shown how things should not be done by exhibiting a slide showing half the dimensions in decimals and the other half in fractions. That was a very common mistake in the drawing office, and ought not to be countenanced by production engineers. If the drawing office wanted decimals they should be used right through, and the same applied to fractions. With regard to general limits, it was time the drawing office gave the workman something he could understand, and the production engineer should insist upon that being done. The author had shown them a system of limits which was very commonly used, but he thought it could be improved. There were four different ways of using limits. A common system was like this:

$$1\tfrac{31}{64}$$
$$+\cdot 005$$
$$-\cdot 002.$$

That was unpardonable, and it was not surprising that the work was done slowly. Another system was:

$$1\cdot 250$$
$$+\cdot 001$$
$$-\cdot 002.$$

This again was very much open to error, because it was quite possible for the draughtsman to misquote a nought or to put the decimal in the wrong place. The simplest method he had seen was :

1·250
+1
−2.

By that the workman very quickly understood what was meant, and it was a system which should be standardised. He disliked numerals, as it was very well known, not only among engineers, but among others, that where they had to refer to some standard to interpret a number the human element was brought in, and there was always a possible chance of introducing an error in interpreting a number.

The author referred to the question of projections as being very important, and so it was. He had seen hundreds of pounds' worth of work scrapped because the projection had not been the orthodox geometrical projection, but was a straight-line projection which was not clearly noted on the drawing. He knew of a case in which work had to be done by putting in the jigs the wrong way round. As to modifications, there were usually three classes which should be stated on the drawing. There was the modification which might be necessary to facilitate manufacture or to use some standard gauge; there was the modification which meant that the moment all the material was used no more should be ordered of that description or any more made from existing castings; and, finally, a modification which was absolutely imperative and should be incorporated immediately and standardised throughout. It was done during the war very successfully. The modifications were called A, B, C; they were briefly described. After putting the required number on the part, there should be some place to indicate that there was a certain modification of a certain class. It was easy then to see what had been done with parts in progress, and there was no necessity for each chief designer or works manager to go round informing individuals concerned that a certain modification was intended. There it should be on the drawing, when each one knew what he had to do.

With regard to screw threads, there were several systems in use. There were the Whitworth and the B.S.F., and the metric was also in extensive use. It was essential, in his opinion, to state the system on the drawing and to give the number of threads per inch. That should be done down to the smallest screw, and it was then easy for the turner to calculate the change wheels without having to find out from a table how many threads there were, even in a standard part. In order to carry out economical and satisfactory production they should insist upon the drawing office giving them, not what the drawing office think fit, but what production engineers know they really want.

Mr. Waring-Brown agreed that nothing should be left to the assumption of the workman. For instance, the author had said that a hole was threaded and it was assumed that it was a right-hand thread, but the drawing should designate the thread and not let the workman assume it. That was particularly so in the motor industry, where there was an intermingling of metric and English measures. The threads for sparking plugs were accepted as

standard, and therefore where there was a variety of threads it should be clearly stated on the drawing which unit it was, the number of threads per centimetre, and so on. Another matter upon which the production engineer should insist so far as the drawing office is concerned was in relation to tolerances. The best way, in his opinion, of denoting tolerances was as follows:

1·250
1·251

because one got a variety of operations, and in a large works with mass production the parts were probably inspected after each operation. If it were stated on the drawing that the limit was between 1·250 and 1·251, one not only instructed the man who made the article, but also the man who inspected it, so that he knew if it were not within these limits it must be scrapped. If it were denoted in that manner it represented definite tolerances, but suppose a shaft had to be dealt with on which there were a turning operation and a grinding operation, then the tolerances could be denoted as:

1·260
1·261 (turning)

and, underneath, the grinding tolerance. In that way after each operation, when the parts had reached the inspection department, the inspector knew the precise limits and whether or not he could pass them.

Another troublesome matter in a works was the question of alterations. As the author rightly said, it was generally found that a drawing turned up in time to scrap another batch. The best way to deal with drawings in a works was to issue a specification covering batches, so that an alteration could not take place until a certain time after the completion of a batch. Instead of altering a drawing it was very much better to issue a new one, so that there was no question of a drawing turning up again and batches being made to the wrong drawing. It was an error to refer to a scale on a drawing, as it was generally found that some person would put his rule on the drawing to measure it after the blue-print had shrunk $\frac{1}{4}$in. Therefore, it should always be denoted on a drawing that the measurements must not be scaled. He thanked the author for bringing up a question of very great importance, because the average drawing office had got into a stereotyped way of doing things which suited the drawing office admirably, but was ill-suited for works' use.

The President said he would like to interpose some remarks here, as he wanted to show a few lantern slides. With regard to tolerances and the notation of tolerances he also held some very strong views. A combination of decimals and vulgar fractions could be made of use, and had been employed by himself and others for the very definite purpose of indicating something specific. For example, "1$\frac{1}{2}$in." would serve for a dimension which need not be very accurate, such as in the case of a number of holes in a coupling with a driving fit. By that means the man who took up the drawing knew that there was no tolerance or that there was a good deal of tolerance on that dimension. In certain cases where there was a diameter with a thousandth tolerance, it was much easier to use a unilateral system and say "$-$1in.," thus:

1·250
$-$1,

without defacing the drawings. The unit might be obliterated and the man make more tolerance than was justified. Therefore, it was best not to confuse the figures, but to indicate the tolerance as he had suggested. Where there were a turning dimension, a grinding dimension, and perhaps a milling dimension on the same piece, the dimensions must be put on the parts.

Here a slide was shown illustrating another means of indicating the tolerance on a drawing. The diameter of the circle was 7in., and with a spherical-ended rod with one point stationary and the other point moving one got $\frac{7}{16}$ths play with a very small error when the hole was $3\frac{1}{2}$ thousandths larger than the main dimension. On work of that kind in large sizes, such as bores for flywheels, which were only made in small quantities, it was very convenient to put on the drawing the size of the hole and the permissible play. Therefore, the tolerance was indicated by "play $\frac{7}{16}$in." or "$\frac{1}{2}$in." or "$\frac{5}{8}$in." The formula for calculating the play was given underneath. It was then easy to make the mental calculation, and he had used that method a great deal.

In the second slide was shown a type of sheet that he used. He certainly preferred the name at the bottom. "Part No." was preferable to "Drawing No.," especially if it were the practice to detail every piece of the work. In that case there might be a drawing number as well.

He considered it was of the utmost importance that there should be only one drawing of any piece in the works at the same time. In a large works some people considered this an impossibility, but he had done it in a works employing over 5,000 hands on intensive manufacture, as well as in a small place employing only a few hundred men. The essential factor for success was one picture of one piece on one sheet of paper. It was hardly ever found that the operations were such that the drawing was needed in two departments at the same time; if so, emergency arrangements could be made.

MR. O. D. NORTH thought that some of the speakers were asking a great deal from the drawing office if the drawing office were to give all the information required by the most stupid man, or the least intelligent man, in the industry. If that were so, the drawings would become very complicated, and for that reason he felt that it was important that standardisation in methods of preparing drawings should be brought about as soon as possible. In many cases it was really impossible to give all the information on the drawing. In certain works some information was omitted from the drawing, it being left to the intuition of the man. It was assumed in those works that everybody knew what was meant. As a previous speaker had mentioned, a man going from one works to another was completely mystified. If it were admitted that it was very difficult in every case to put all the information on the drawing, then it was of vital importance that it should be agreed as to what should or should not be shown.

It appeared to him that production engineers were obviously the officials to criticise the shop drawings, because they were responsible for production, and it was within their province to take steps to secure what they wanted.

With regard to this question of standardisation, could not a simple *questionnaire* be sent to the members, either through the medium of

the official journal or in some other way, so that an idea could be obtained as to what was the common practice? Take titles, for instance. He agreed with all the other speakers, except the author, that titles should be put on the bottom right-hand corner. It seemed to him wrong to put them in the left-hand top corner, as suggested by the author, because, generally speaking, the drawing ran over the length of the paper, and that meant that in a 20in. drawing the title was at right angles to the lettering and the writing on the drawing. That was a very important matter in the works and for other people who had to handle the drawings.

One section of the works which criticised the drawing office as much as any was the buying department. He could not help sympathising with the buyer who was told to get out hurriedly about 5,000 different things and had to turn up the drawings for the purpose. It was essential that titles run parallel with the lettering and writing on the drawing, and always be in the bottom right-hand corner. There had been a big demand for process drawings, and the trouble was to know where to stop, because they could become such very elaborate things. It was a good idea to make the general drawing before they made a detail drawing. Then one could realise how much it was going to cost to make the part, and perhaps modify it in time.

The author had illustrated a piece of boring work, and the view was projected in what he believed to be the American fashion. It was turned over so that they saw the small circles individually. That was a point which ought to be settled, viz., what was to be the customary projection? He thought the idea of showing the piece in the position it first assumed in the lathe, as the author had illustrated, was a sensible one, but it might lead to trouble sometimes. That was a point which might usefully be discussed, but, at any rate, it would be quite a good idea if some information were obtained with regard to the position of titles and methods of projection, and whether issue numbers should be used on drawings. If they could get a few simple things like that settled first, if possible throughout the whole engineering industry, and if they did not ask an overworked drawing office or production department for too much elaboration, it would be a good start. The information could be obtained by sending out a slip of paper with the questions, so that the desired practice could be readily indicated.

MR. GARTSIDE said that with some of the points in the paper he agreed, but with others he did not. Most of the speakers had been referring to mass production, but he was in the position of having to make many different machines, so that many of the refinements related to drawings containing information he was not able to carry out because the process would be too protracted. He was not deprecating the suggestion that drawings should contain as much information as possible, but was only pointing out a case in which it was not possible to go to the lengths suggested.

He disagreed with the author as regards the folding of drawings, as again too much time would be absorbed. Drawings should be laid flat, whatever size they were. He would like to describe a system which he originated in a works some years ago. Drawing office furniture was to be purchased, and the question arose of sizes in drawers. The system he devised was quite a simple one. There were three departments in the drawing office—the estimating depart-

ment, the department that made the working drawings and the details, and another department which dealt with parts made on mass production lines. He employed the same system of filing and storing drawings in all three departments. The basis of the system was the double elephant sheet of paper. Standard furniture and drawers were purchased to accommodate the full-size sheets. The three department were indicated by the letter E for estimating, T for tools (which were machine tools), and the third department, which was called the manufacturing department, was denoted by the letter M. The titles of the drawings were put at the bottom and the name of the firm was on the top. The tracings were all arranged with spaces for information, as the author had illustrated, and on the bottom right-hand corner was the space for the contract number. Each number had the indicating letter according to the department. Then there was the space for the drawing number. That was for the full-size sheet, and a drawing would be numbered $\frac{1000}{1E}$ for example, indicating the department to which it belonged. The next size drawing was half the double elephant size, the full-size sheet being divided down the centre, with a small allowance cut off to enable the halves the more easily to get into the full-size drawer, down which was then put a batten to keep the halves apart. Thus he got two lots of sheets in a standard drawer. These half-sheets had the titles on the bottom as before, and were numbered 2E. The double elephant sheet was divided up until it got to one-eighth the original size, and the drawings then were called 8E, or whatever letter was required according to the particular department. He did not get down to one-sixteenth size, because the drawings then became too small. In the estimating department he always tried to keep the drawings to one-quarter the double elephant size. This enabled the work to be done much more quickly, and also, if they made the drawings the full size to make them look attractive to the prospective customer, too much detail had to be put in. After the order was secured, then the details could be settled. Further, the quarter size sheet was very handy for anyone on the road. In this way the drawings were filed away in separate drawers according to their numbers, 1–100, 101–200, and so on, and in a single drawer some 400 drawings could be filed in the case of the quarter sheets. Before he had this system all the drawings for all departments were run in consecutive numbers, and in all sizes in the same drawers, but with this system he was able to cut down the space occupied to a minimum.

As to indexing, he had a master book which was printed and ruled with four columns, and five columns in the case of the one-eighth size, E1, E2, and so on, for the three separate departments. In that way a drawing could be found by anyone almost immediately, the numbers of the drawings as they were finished being added to the book by each draughtsman. There was also the usual card index for the various sizes, but the book was used for all sizes, a separate book being utilised for each of the three departments. The system had been running for some years very satisfactorily. The titles of the drawings were arranged so that they were always in front at the bottom. All this was not by way of criticism of the paper, but as an addition to it.

He had always found a great difference of opinion in the drawing

office with regard to the question of projection. He, however, stuck strongly to the orthodox system of projection. He himself had been in the shops before he went into the drawing office so that he could appreciate both points of view. At one time he had great sympathy with the works, but now it was with the drawing office, and he did not think the drawing office got sufficient credit.

On the question of projection he thought it was largely determined by the type of equipment they were using in the drawing office. If they had ordinary drawing boards with a parallel rule that would really make a line parallel—and a lot of them did not, he was afraid —then they could afford to adopt the ordinary technical school projection. If they had a T-square that was not rigid, then the best thing to do was to put the side view as near as possible to the end it denoted, because then there was less chance of errors in dimensions.

The minute figures which were found on many drawings were the cause of much complaint in the works. He introduced a system by which all the figures were standardised. Little celluloid markers were devised which gave three dimensions for figures, and by the use of these markers the draughtsman could draw light lines on the drawings and fill in the figures between the lines. Thus the lettering was standardised in three sizes, according to the size of the drawing. The idea emanated from the practice of the Westinghouse Co. at Manchester.

Mr. Kenworthy agreed with most of the things the author had said. With regard to drawings made for purchasing purposes, he always called for the part number, in the case of stampings or castings, to be cast or stamped in position where there was no subsequent facing, and also for the identification mark of the stamper or caster. This was very useful in the case of rejections or for obtaining spare parts.

The dimensions should be noted on the drawing in such a manner as to avoid the subtractions or additions which were now too frequent in order to get at the right dimension. Each dimension should also have its tolerance or limit given in the view. Where a standard system of limits was in operation, such as the Newall, and, say, a gear had to be fitted on a shaft, owing to the different lengths of bearing and the nature of the material—it might be a hardened gear and a hardened shaft—a push fit might be sufficient in some cases and a driving fit in others. But the drawing office often rigidly adhere to the idea that a gear must be fitted with a driving fit because it was recognised as necessary from the drawing office point of view.

There was a very great desirability for absolute concentricity of parts. In the case of a gear the centre should register and the face should run absolutely true. Otherwise, if there were any eccentricity in the gear centre, it would cause very bad running on the periphery of the gear. That was a point he had never yet seen made on a drawing. In the case of a shaft, if there were four or five parts to be built up on the shaft, and they had to be bolted together, if there was the least bit of inaccuracy in the parallelism of the faces, then the shaft would be thrown badly out of truth. The kind of drawings in use in a shop was determined entirely by the class of manufacture and the methods adopted by the particular firm.

The whole question resolved itself into whether the drawing office

was the production department. The drawing office, in his opinion, was there to design the machine or some other part. The works were there to produce it. Then the question arose as to who were the people to make the drawings from the process point of view. Who were going to determine the processes? The drawing office would if it were given the information, but the drawing office frequently had not sufficient experience in actual shop production to say in what manner a part should be manufactured. Then again, there was the tool-room drawing office which had to be taken into consideration. The tool-room drawing office had to make the jigs. The most desirable procedure was for the designing drawing office to be satisfied, in making a drawing of the article, that every dimension that was desirable was given on the drawing. The tool-room drawing office could then make a series of process drawings, gradually working up from the rough bar or the rough casting, showing each separate operation, showing what required to be done, the number of tools and gauges necessary, and so on. That seemed to him to be ideal. It was an elaborate system, but it separated the actual designing drawing office from the shops, and left the shop to work out its own salvation. He did not consider the drawing office was the actual production department.

A good method of denoting sizes of drawings in the case of mass production was to use prefix letters, such as A323, B323, and so on. The numbering in each case would be consecutive, and not intermittent in any way. If the parts had to be made for different machines, or where the number of machines was not very great, or for different parts of a chassis, for example, then another letter could be used behind the number which would denote what part of the chassis to which the drawing referred. In this way B could be used for back axle, C for control parts, F for frame parts, and they would get such a number as B323F. They could then recognise by a glance at the drawing to which part of the machine or component it related.

Mr. Gerard Smith speaking with regard to limits, said he was glad to see at last that the +1 and −1 method of delimiting was coming into use. It had been used in both large and small firms very successfully, but there were a few things that needed to be known about it. The nominal dimensions and the limits on either side should always be stated. In the case, say, of a 1in. shaft, "1 inch plus and minus" should be indicated. When they were using a micrometer, one usually read 1 inch minus 2, and if the drawing were marked in that way it would be helpful. There were many dimensions that were quite unessential on a drawing, and it was possible to avoid covering a drawing with figures by means of the plus and minus method.

With regard to operation sheets and detail drawings, production engineers did not want detail drawings; they wanted operation sheets. The operation sheet should give a drawing of the part and all the dimensions. Take the case of a stamping. Once the die was cut one could not go wrong, provided the die was checked; and the radius could then be omitted from the operation sheets from the production point of view. It was wanted on the detail drawing. The operation sheet should contain a description of what each operation was, and what tools, jigs, and gauges were required.

He entirely disagreed with the previous speaker when he said that the drawing office should not decide operations. He personally

claimed that a man was not a draughtsman until he had had a long shop experience. He would even go further. In many shops the chief designer had to design the tools to carry out his ideas; then they had the tool drawing office perhaps at the other end of England, and the whole of the designer's work and his knowledge was wasted and thrown away because his ideas were not carried right through to the final operation. The drawing office should send out every drawing. That had one disadvantage, he agreed, and that was that the man in the shop complained that he was not being taken into consideration in the manufacture of those parts. In that case, the only thing to do was to call a production meeting of shop foremen, inspectors, draughtsmen, and toolmakers, in order to decide how they were going to work.

A part number should always mean something. If one were producing lathes and milling machines, one could say "10,000 lathe," "20,000 milling machine," and so on. By such a system there was room for 99 assemblies. If 101 was the general assembly for the headstock, it would soon be remembered that that was the first assembly in the lathe. That system could be used in parts of machinery in which there were hundreds of operations, and it was working excellently, and the people in the shop were beginning to know what it meant.

THE PRESIDENT said that with this system one could only have nine different types of lathe in the shop.

MR. GERARD SMITH said there was nothing to prevent one going to six figures. The numbers he had given provided for nine types of lathe because he did not anticipate producing more than nine types in that particular case, but if they wanted to produce more, then one more figure would give them 99 machines.

The filing of drawings was sometimes a controversial subject. The production engineer, when he wished to talk about a job, required detail drawings, operation sheets, drawings of the jigs, tools, and gauges; in fact, he wanted the whole story. If the draughtsman desired to make a general arrangement or make alterations in the general arrangement, he would also want a bunch of drawings. He himself had started a system of putting everything in a bag, relating to a part number, but he found that he wanted about twenty of these bags, and he gave it up. As to the Photostat process, he could not help feeling that this was a costly luxury, unless they were employing 10,000 hands. The apparatus cost about £300, and the prints cost something like 10d. or 1s. each, instead of 3d. or 4d., and anything above 24 inches square was not obtainable commercially.

MR. W. H. STOREY said that on one of the lantern slides that had been shown it appeared that half the small size sheet was taken up with columns in which to indicate alterations, and a lot of other matter. That ought to be cut down to an absolute minimum.

The author had also mentioned, in regard to one of his slides, an issue number or letter which indicated how many sets of prints had been taken off that particular drawing. An alteration number had also been mentioned. He himself would have imagined that that alteration number would do equally well for both purposes, and in that way some space could be saved on the drawing. A combined blue-print and drawing register was almost essential. In some shops with which he had been connected there was a blue-print register which was purely and simply a blue-print register, and if one

wished to find out how many prints had been taken off a particular drawing, one had to go back something like ten years.

He had known cases where vulgar fractions to the 64th had been used, and on the same drawing plus or minus 10 or 20, as the case might be, had also been used. There was something to be said for a method of indicating tolerances by 1.250 and 1.251, but it must be borne in mind that that did not give the nominal dimension, and, after all, it would be better to give some nominal dimensions, to which the shop should endeavour to adhere. One thing causing confusion at the present time—and it was noticeable in the author's slides—was that the dimension lines were not staggered.

He agreed with one of the previous speakers that the number of threads should always be shown, because it saved a considerable amount of time. The workman never received a check, and although he might check it himself very carefully where the number of threads was not given, the result was always doubtful. There should always be a check, and then there was little likelihood of error. That not only applied to threads, but generally. Drawings should be so dimensioned that no calculations should have to be done in the shop. That was particularly important on tool operations.

He certainly agreed that projection should be standardised all over the country. It had caused considerable confusion, and there was a lot to be said for the American system of projection, even though the so-called English method might be the more theoretically correct.

As to filing, he did not think the draughtsman's time should be taken up with this. It was much too valuable, and an office boy should be employed for the work. A standard filing place should be provided in each office—he was speaking of the smaller works where they did not have a drawing store—in which the draughtsmen should place their drawings for filing, and they should then be filed by the office boy. When any drawings were required out of the files, then the boy should be requested to get them and book them out to the draughtsman who wanted them.

MR. LEE said that in the first place he considered drawings should be as simple as possible; by that he meant that a thing that was obvious from other views should not be included on other drawings to fog them. He thought it was a good idea to use vulgar fractions on the drawings for shop use. There were some educated establishments where the metric system was understood, but in the majority of cases the workman was frightened at the sight of a decimal.

Nothing had been heard about showing machining marks in red on the drawings. That was certainly very attractive to the eye, and easily grasped, and it was much better than a lot of dotted lines running round the part.

As to filing drawings, he did not think one could better the simple card index system. When drawings came out they were recorded on the cards, but whatever system was used it involved the human element, and that was where all the trouble lay.

MR. BUTLER said that with regard to limits for tolerances, where there was a tolerance it might be put in decimals, both maximum and minimum, and where there was no tolerance, fractions might be used.

As to the numbering of shop drawings, it had been suggested that this should be in the top right-hand corner or in the bottom left-hand corner, but it was not a bad plan to put the number in both

places. That facilitated getting at the drawing, and he had seen it working quite well in some large firms.

Not much had been heard about the class of paper used. That depended a good deal on the nature of the work and the number of prints to be taken off. Sometimes it might be possible to use thin tracing paper, and at other times cloth would be necessary.

With regard to the Photostat process of copying, this was a very convenient method where there was only one copy from which prints were required.

As to having a separate view for each operation, that was going rather far. It was more than could be stood at present, when every effort was being made to produce economically and cheaply. If a drawing were clear and concise, and had the necessary measurements on it, the operation drawing, except in exceptional cases, was totally unnecessary. If there were assemblies of small parts consisting of 70 or 80 components, sometimes with seven or eight operations on each, something like 300 or 400 drawings would be required to one assembly, and they would take some sorting and much watching.

The President had mentioned that he had found it possible to use one drawing for one piece. That was interesting, but he would like to know where the drawing was kept. A firm employing 5,000 men, as had been mentioned in this connection, must be a fair size, and the drawing had got to be kept somewhere. In that case, somebody would have "a little run" for that drawing, no matter whether it was in the particular place where the man went. The drawing office probably wanted a copy, then there was the machine shop, the inspection department, the purchasing department, the estimating department, and the production engineer. They would all want to have a look at it some time. He agreed that the fewer the number of prints to any particular drawing the better, because alterations could not be avoided, and the drawings would be lost despite all precautions taken for their safety.

The operation sheet issued by the production department should cover the tools, jigs, fixtures, and the method of making. He agreed that the production engineer's department was the department to say how the piece should be made. He also agreed that a draughtsman was not a draughtsman unless he had had shop experience. Even if he had had shop experience and later had been a draughtsman for many years, some of his methods might get out of date. It might happen that if he said a piece were to be made in a certain way, the machine-shop foreman would say that he had a machine that could do it, but he had half-a-dozen others specially made for doing that operation in another way.

MR. GUYLER, replying to the discussion, stated that he agreed with what had been said on the subject of the standardisation of drawings. The difficulty was in trying to adapt one's own system so as to conform with the standardised procedure. He himself was trying to do that, and Mr. Fairbrother would have his sympathy when he came to do it.

With regard to the description being at the top or the bottom, he was afraid he himself had rather lost sight of the fact that drawing numbers were sometimes at the bottom, because for a number of years he had been in a works where the drawings, or the majority of them, were filed in vertical files. It was then very awkward to see the drawing number if it were at the bottom, and it would be

necessary to force the drawings apart to see the number. Therefore, where vertical filing was used he should certainly recommend that the numbers should be at the top.

Dealing with the question of putting operations on the drawings, if they were single-operation drawings, he agreed; but if it were a case of detailed drawings, then there was too much complication. An operation sheet was certainly very much better. The same applied to jigs, tools, and gauges. In the case of an operation for only one part, then certainly do it, but it added to the complication if they had, say, forty operations. That might appear to be a large number, but he had known cases where forty operations were required, and, by the way, the weight of the casting was not more than 6lb. If they had to enter all those operations on a drawing, and also the jigs, tools, and gauges required, then they were getting into something more like a library than a drawing. He preferred to use decimals wherever possible rather than mix decimals and fractions, but if they had a $\frac{3}{16}$ths Whitworth thread, he would sooner say $\frac{3}{16}$ths than 0·1875. To state the number of threads was useful, but in the case of threads which were produced by tapping and dieing he did not think it was always necessary, particularly if they mentioned, for instance, $\frac{5}{16}$ths Whitworth. In that case they would have a standard die or a standard tap, and there was no need to add the number of threads. If it were an odd number, then it might be added, but in the ordinary way the point was covered by the simple mention of the word "Whitworth."

On the subject of tolerances, to limit the dimensions was very good, and many of the methods were excellent, but here again the choice was one of personal preference. In cases where there were a turning size and a grinding size, he had seen the turning size put in a square and the grinding size by the side of it. If that were understood—another case of understanding—or there were a note on the drawing, it seemed quite effective.

As to measuring the size of a hole by means of the play in a pin gauge, that was very good, but it meant that the workman or someone had to make a measurement, and there was the possibility of error if the pointer were not set in the two positions at the same time so that a rule could be got across it. Otherwise it was rather awkward measuring play in a pin gauge.

Mr. North had raised the question of omitting much of the information and leaving the matter to the workman. That was all very well, but if that were done it would be found that in a few years' time most of the information was being left to the man in the shop. It would be discovered in due course that the accepted practice had been departed from, the man who had formerly carried it out having left or died. Such a case was by no means uncommon.

In reply to Mr. Gartside, he himself was engaged on work where they never built two machines alike. He would not go so far as to say that the firm had never built two machines from the same patterns, but, if so, it would be after an interval of many years. An effort was made, however, to get down to a production basis and still make the machines different every time. A good many of the components were alike—that is, there were parts which were of similar shape and varying dimensions; they varied according to the conditions given on the order.

As to drawings not being folded, large drawings were rather

awkward, but it was an advantage to file them flat and file them altogether. The man in the shop did not want to know the different sizes of drawings; he was interested in where they were and how quickly he could get them. The matter of sizes of drawings and the filing of the original drawing were matters of drawing-office system which could be left to the drawing office. As a matter of fact, a number of the speakers had raised the question of drawing-office system, which he had tried to avoid in the paper. There was enough matter in that subject for another paper. As to lettering, script was not so clear as block type.

He agreed wih Mr. Kenworthy that the mark of the caster should be on the parts so that they could be recognised. Fits and length of holes depended entirely on the man who was deciding the fits, and that brought in the question of whether it should be the drawing office or not. It did not matter much who decided it so long as the correct information was put on the drawing. It had been said that perhaps the man in the drawing office had not much experience. He used to think so himself when he was in the shop, and he now sometimes thought some of the things with regard to the shop that he used to think with regard to the drawing office. It certainly was a good thing for a man to go from one to the other, because it kept him up to date.

With reference to the question of eccentricity and parallelism, personally he had found that where this could be omitted from the drawing it was better. If the man had a good balance on the job, even if it were not always concentric, it was all right. It was a question of whether the slight additional eccentricity obtained was important. If it were, then it should be dealt with beforehand, but if not it was better to leave it out, taking, of course, the ordinary precautions in manufacture. In any case, the operations should be decided before the detail drawings were made or while they were being made. Very often, when they were making out the detail drawings, it was possible to see things which they could not see in a general arrangement. If the draughtsman had any experience of production at all he could very often find out whether it was good practice to do any particular operation or not. The draughtsman certainly had a good opportunity of checking over methods while he was drawing.

The use of figures to denote the assemblies of complete machines had been mentioned, but that, again, was a matter of drawing-office system rather than the drawings themselves. The difficulty he had encountered, especially if a number of machines of rather similar design were being made, was that a certain part of one machine was given a number, say 10199. It meant that that belonged to machine No. 1; that it was assembly 01 of No. 99. That part was also used on another kind of machine or another size. The question was whether it was to retain its old number or be given another. When this particular machine became obsolete they then had a number belonging to a machine which had been obsolete for a number of years, and it made it rather awkward for the notation.

He agreed that the cost of the Photostat might be rather high, but in some cases the time and labour saved and the avoidance of errors in copying justified its use. There was no need to buy a machine if it were only wanted for intermittent use. There was usually a near-by firm where a drawing could be copied.

Mr. Lee had suggested that drawings should be made simple by omitting the obvious. But the question arose as to what was the obvious. What appeared obvious to the draughtsman did not always appear obvious to the man in the shop. Marking the machined parts in red was very good, but it meant that every time a print was taken, one had to go over it and put in red lines, which was rather a disadvantage. If it were done on the tracing, the red line only showed faintly, and it was apt to confuse rather than help.

The question of the quality of the paper to be used was determined, in most cases, by the man who settled the cost. Very often they did not get the paper they would like. If the drawings had to remain in the shop for a long time, a good plan was to have them mounted and varnished, and then it did not matter what quality paper was used.

As to having 300 or 400 drawings to one machine, which one speaker mentioned, the machine which he himself was engaged on at the present time had as many as 1,200 to 1,400 parts, and he managed without difficulty.

Perhaps it was not one of the functions of the drawing office to settle operations. The drawing office had as much as it could do at present, and in a well-organised works there should be someone or some department whose sole job it was to settle the operations. If that could not be done, there should be a committee of works foremen, drawing office, and production engineers formed, which would enable these things to be settled.

THE PRESIDENT, in bringing the meeting to a close, said their experience that evening had justified the alteration in the day of the meeting from Saturday to Friday. There had been a better attendance and a splendid discussion.

COMMUNICATION.

It was with great pleasure that I listened to the paper on "Drawings and Production," and the interesting discussion which followed, and regret that owing to the lateness of the hour I was unable to speak at the meeting. The matter is a most important one, and I should like to submit the following.

Obviously the drawing should give the whole of the information in regard to the part as regards dimensions and particulars of the threads, etc., required by the works, but here I consider that the details of the works drawing should end. Further, I do not think that operation drawings are necessary, as these may easily be confused in the works, with a resulting quantity of scrap, and the information required can be given in other ways, which I will mention later.

In regard to projection, I believe that the theoretical method is the best, and I think that it is a pity that the American system was ever allowed to become mixed with our own, as it has tended to confusion. If, however, one system is followed throughout, and the system is definitely stated, confusion will not arise, but unfortunately the two systems are often mixed.

As regards preference for the American system, as it permits the use of faulty instruments, I would suggest that one would not permit the use of faulty instruments in either drawing office or works, whatever work was being done, or system was being used. Accurate instruments and workmanship are as important in the drawing office as in the shops.

A point which does not often receive sufficient attention are the considerations as to clarity of line and exact location of information, which make the drawing clearly intelligible to the operator in the shops.

I do not consider that it is possible to include a planning sheet on the drawing, nor do I think that the drawing office is the place where this planning sheet should be made out, unless it is under the control of the production engineer. Surely this work belongs quite definitely to the production engineer himself, and I am rather surprised that this apparently was not appreciated at a meeting of this Institution. The information in regard to operations should be given on a master planning sheet, which forms the basis of the whole of the operation system in the works, and, given that the drawing is clear, there should be no further difficulty in regard to the work which will be produced from it. All points should be dealt with by the skilled production man in the planning department, leaving the operator little chance for error, provided that the essential quality of clearness in the drawing office is observed. I do not wish to labour this point, as obviously the question of system is not included in the paper.

In regard to modifications, I think it is absolutely necessary that a note of all modifications should be entered on the drawing itself, and clearly indicated by some means on the modified dimensions.

Limits should always be clearly shown, and I personally favour the method of giving them as two different dimensions, as this avoids any calculation in the works itself. In regard to dimensions, where no close limits are necessary, it is usually understood that there is an open limit, say, plus or minus 0·1 millimetre. This amount varies, however, according to the class of work which is being handled.

With regard to the position of the name of the part, the drawing number, or part number, I think this is a matter which depends first of all on the governing factor in its identification, and the ease with which that point is located in the filing system used in each works.

I must congratulate the author on his excellent paper, and his courage in raising matter on which there is so much controversy.

J. BELL, M.I.P.E.

25, Victoria Street, S.W.1.

THE
INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting was held at the Institution of Mechanical Engineers, London, on Friday, December 30th, Mr. Max R. Lawrence, President, being in the chair.

The minutes of the previous meeting were read and subsequently confirmed.

Mr. G. H. Hales then delivered his paper on "The Costing System and its Relation to Production."

In the discussion which followed, a number of Members and visitors took part, and the general opinion voiced was that Mr. Hales' paper was of considerable value to the Institution.

The President announced that it was intended to hold informal meetings in Birmingham and Coventry towards the end of January.

Votes of thanks to the Author of the paper, and to the Institution of Mechanical Engineers for the loan of the hall, concluded the proceedings.

THE COSTING SYSTEM AND ITS RELATION TO PRODUCTION.

By Mr. G. H. HALES, A.F.R.Aë.S., M.I.P.E. (Member of Council), Works Manager, Messrs. Drummond Bros., Ltd., Guildford.

Foreword.

The aim and object of this paper is to show the value of co-ordination between the costs department and the production departments.

The first point made is the necessity for making use of the production man's intimate knowledge of works conditions when drafting forms relating to cost of manufacturing operations, so that better provision can be made for self-explanatory indications of scrap, and unusual conditions which result in correspondingly abnormal production cost.

Secondly, the necessity for more assistance from the cost department in the shape of day-old figures of cost to be supplied to the works executive as a constant guide in effecting economy in production, and also for discovering abnormal expenditure on any given part or operation. If necessitated by the conditions of the business, the expenditure may be given accumulatively. Take, for instance, the case of a general engineering business where, for the purpose of submitting a tender, work is estimated for by the costs or estimating department. When a contract is secured, only a certain percentage of the estimated figure can be allocated to wages. If daily accumulative costs or expenditure be put in the hands of the production engineer he will be able more readily to prevent excess cost, or to take such steps as will minimise loss. Returns may be quoted in hours or money as best suits the business. Mr. Rowan, of the Clyde Engine Works, who may be regarded as an authority on works system, has his returns made in hours.

Thirdly, to emphasise (*a*) the essential need of making wider use of practicable records relating to expenses other than wages and materials, *i.e.*, establishment charges; and (*b*) to illustrate the value of bringing such details before the notice of the works executive, so that they may assist in effecting economies when laying out a new type of manufacture. For general convenience, this point is dealt with first.

The persons usually delegated to draft the system connected with establishment charges and to set out their distribution are the firm's secretary and cost accountant. They make use of all available records relating to constant expenses, and estimate to the best of their knowledge and in accordance with the firm's policy for the remaining factors. The total figures or even the analysed rates are rarely accesible to the average production man in a works, or, if they be accessible, full advantage cannot be taken of the figures, owing to lack of knowledge of their detailed compilation.

It is frequently argued that the works executive should not be concerned with establishment charges and their distribution. If, however, it be made clear that the works do not desire in any way to usurp the functions of another department, it is difficult to see any objection.

If the works executive be given access to the figures it will be better appreciated that the greater portion of the expenses covered by establishment charges are incurred by the works administration. Unless the detailed figures of expense be brought to the notice of the heads of departments to enable them constantly to compare expenses with results, it is in effect giving them a blank cheque and trusting to providence for them to "make good."

The direct time taken and wages paid to an operator for a certain production operation are carefully recorded, and economy or excess can be brought to notice, but the expense of employing an extra non-producer in any department might pass unnoticed because this would be booked against the administration account.

The subject is far too extensive to permit of its being dealt with fully here, and it has therefore been treated from the aspect of the production man. It is not necessary for a production man to concern himself with the cost accounts and system other than those which have direct relationship to economic production.

It is generally understood that the duty of the production side of a works is to produce the goods in the most economical manner. The duties of the cost department are less generally understood, and to define the function of this department the following is submitted :—

The cost department shall collect and collate accurate records of expenditure incurred in the carrying out of a business, and be responsible for the correct sub-division of cost figures necessary to the wages and accounts departments.

The cost department shall also provide and supply the works executive, buying and selling organisations with all cost records in detail necessary to enable them to put their finger on the high spots of cost in any and every stage of manufacture.

The cost department shall also furnish the statements required by the directors of the business.

The essential factor in compiling the statistics is, of course, accuracy, which is very largely dependent upon the system installed for obtaining the information required to build up the cost figures.

It is generally realised that the people in the works prefer the minimum of clerical system, since this is not their function, and therefore when abnormal and perhaps unavoidable conditions arise which are not covered by the system a chance for avoiding a later day trouble is missed. The abnormal conditions are often the stumbling block of the cost department, and unfortunately a ready source of friction between the members of works and office staffs.

The cost officials, of necessity, relying solely on interpretation of facts on paper, as supplied by the system, often produce totals which, if recording abnormal cost, would appear to warrant the attention of the general management. For example, in repair work on, say, an old-type product, calling for "one off," it is not uncommon for excessive cost to go undetected until the account is queried by the customer before settlement, with the result that the cost records are then checked and compared with past records. Under certain

conditions very excessive cost against the item of complaint might be shown. Such figures reviewed by a managing director would prove, *prima facie*, a case against the responsible head of the production department, and would warrant close investigation. In all probability the head of the production department would be sent for and confronted with the figures for which he must give an explanation. After a great deal of trouble in bringing to light a long-forgotten incident, he would perhaps find that abnormal conditions were the cause of high cost, and might report: "Manufactured by tool-room methods (no jigs or special tools available); and one casting scrapped due to blow holes discovered on final operation." While this might be a perfectly reasonable explanation at the time, a belated explanation is unsatisfactory and may leave the impression of "excuse" rather than "explanation." The natural result is that the works man blames the cost department for producing what he considers inaccurate figures, and this state of affairs tends to cause friction and consequent lack of co-ordination between works and cost departments.

After analysing a number of cases of this description, the author has found that the system does not fully provide for local conditions, which are only apparent to the shop man. It is almost impossible for the estimating department to give a fair estimate for an obsolete part. If they attempt to do so they will probably work from original batch cost figures plus some hypothetical percentage. This is an unsatisfactory method of estimating, but a practical co-operation between the works and office would make it possible to estimate the cost in a manner satisfactory both to the works and to the customer. The works could then make provision for producing the part according to estimate.

The illustrations given show the necessity for close co-ordination between the cost department and works. While it should be clearly understood that the functions of the cost department are not to be subject to interference, it would be advantageous when drafting the shops system and relative forms for a suitable production man to be vested with power to direct the efforts of the cost department into channels which will enable the system to produce the results required by the works, and also for cost office purposes, for the following reasons:—

(1) The production man alone has the intimate knowledge of shop conditions and exigencies, and can therefore make suitable provision for their recording in the proper place.

(2) He alone can effectively fit the system to the works conditions rather than fit the works conditions to the system.

(3) He alone must explain to foremen and workpeople the necessity for strictly adhering to the various points of the system. Unless the system is partly a works executive's creation, it is almost impossible for the heads of the production departments to realise fully the necessity for strict observance of the rules of the system. The foremen, and finally the workpeople, cannot be expected to carry out blindly something which appears to be unnecessary red tape.

The system and organisation for a business cannot, then, take any standard form, but must vary according to local conditions. While the whole of the various forms, card indexes, charts, etc., are interwoven with those particularly relating to costs problems, it is proposed to deal with the broad lines only of the system, and to give

particular attention to the weak spots and points of failure, from the works aspect.

After studying closely the subject of this paper, and after taking into consideration the usual *modus operandi* of the prominent production men of the author's acquaintance, it is considered that the cost department might play a more important part in economic production than it generally does at the present time. That is contingent on the cost system supplying the production men with up-to-date records of manufacturing operations within, say, at the most, two days from the completion of any operation.

To be fully utilised, the figures must include the establishment charges definitely concerned with the actual manufacturing, as apart from buying and selling charges over which the production men have no jurisdiction. For this purpose it is necessary to sub-divide the allocation of establishment charges, so that they are to the nearest degree traceable to a machining operation. Further, the details of the establishment charges should be constantly before the eyes of the production managers, since it is a fact, in present-day engineering businesses, that establishment charges account for from two to four times as great an expenditure as either actual operators' wages or actual purchase price of raw materials.

Correspondingly increased attention must therefore be paid by the production man to effecting economy in this portion of production cost. It is essential, moreover, that this portion of production cost be better understood by foremen and workpeople, since one often hears remarks among workmen to the effect that all they got for making an article was, say, 1s. 6d., while it was sold to the public for 10s., selling charges, establishment charges, and even the cost of the raw material being apparently ignored. This might not occur if the principle of establishment charges were more freely discussed and put in elementary form for general enlightenment. The process of education on the subject would require careful handling to suit varied circumstances, and the methods to be adopted could not take a standard form, but would depend upon the size of the works and on local facilities. A great deal might be done in this direction if the technical schools included in their curricula lessons in rate-fixing, costing, estimating, etc. It is believed that the headmaster of a large school in London proposed, two years ago, to include these subjects in his course of lectures.

A hypothetical case which may fit any engineering machine shop is the machining of a piece having a number of different dimensions, and capable of being performed on several types of machines. The production engineer has to decide whether the piece shall be machined by multi-tool or simple-tool methods. It will be assumed that the quantity is reasonable to justify either method. When the multi-tool machine is set up, it may produce 40 per cent. more quickly than the simple-tool machine, but the capital outlay—for which interest must be earned—the horse-power absorbed, the tool lay-out, and maintenance, are each in varying degree greater than the simple-tool machine. The natural tendency is for the production man to plump for the multi-tool machine, which is more spectacular, and can perform the operation in shorter time than can the simple-tool machine. This means less direct wages and apparent economy—all other factors being equal. But true allocation of establishment charges might prove that the balance of economy was decidedly in

favour of the simple-tool machine, the determining factor being purely establishment charges, hence the value of detail figures which can be applied to a given operation. To take full advantage of these figures, in general practice, the works should tackle the system problem in closest co-ordination with the cost office and accounts department, and a competent man should be delegated to deal with the question.

In the first place the works man must have a first-class practical and technical knowledge, and hold a high position of authority on the works executive. He should obtain from the heads of the cost and accounts departments the detailed information they require, and ascertain the "grooves of system" necessary to the office side of the business into which the works system must fit. He should then obtain knowledge of the expenses or establishment charges to be borne by the business, the details of which should be given special attention. Such matters can only be dealt with in conjunction with the accounts department, as, since expenses cannot be standardised, it is necessary to estimate certain items, and to rely for a guide on actual records of preceding months. It is in this respect that local knowledge of the manufacturing operations will be valuable and tend towards relative accuracy in distribution of establishment charges.

Below is given an example of a costing system dealing with works cost and allocation of establishment charges. This item is purposely detailed, as would appear to be justified, from the production man's point of view.

Costing may be divided under three headings:—

1. *Material Cost*—which may be defined as the purchase price of, and total expenses incurred in, the purchase of raw materials and factored goods, outside the actual works administration.

2. *Works Cost*—which may be defined as the total expenses necessary to manufacture, as apart from heading 1.

3. *Selling Cost*—which may be defined as the total expenses incurred after the product has reached its final stage of manufacture, including advertising, transport, insurance, etc.

Works Cost may be summarised as *Operators' Wages* and *Establishment Charges*. Establishment charges should be sub-divided, so that all manufacturing operations carry their due proportion of these costs. A method of sub-division is given in fig. 1.

(*a*) Will record the *capital outlay* or *buying cost* of machines.

(*b*) Shows the *comparative production value* as a basis for calculating items (*e*) and (*f*), being a more accurate figure than item (*a*), since the buying cost of one machine may have no near relation to the buying cost of a similar machine already installed in the same department.

For example: A standard type of machine purchased under exceptional conditions, such as surplus or bankrupt stock, for, say, half the accepted market price—item (*a*) would record a buying profit and (*b*) would show the true comparative value.

It is advisable to keep the production value as accurate as possible at all times, and a general adjustment should be made in the case of exceptional universal change in market price of machines, so that the figure really represents the nearest up-to-date valuation. Adjustment of the figure of production value should be made periodically to balance depreciation of its producing capacity, such as general

wear of slides, gears, etc. Item (*a*) should be entirely disregarded in connection with this calculation.

(*c*) Records the *actual floor space* covered by the machine.

(*d*) Records the *nominal horse power* required to drive the machine under load.

(*e*) *Depreciation and insurance* may be termed a constant expense to be recovered in the form of a percentage charged on production value—item (*b*)—plus cost of repairs and maintenance in an estimated period of time, after which it would be more economical to scrap and replace by new machines rather than to repair and maintain. This period may vary from five to fifteen years, according to the type of machine and the description of operations. Insurance charge will be based on valuation calculated from the above. The yearly expense for these items is divided by the machine's productive hours,

	DESCRIPTION OF EXPENSE	Mc. Nº Date				Checked with accounts and re-adjusted					Checked with accounts and re-adjusted				
		£	s.	d.	PER HOUR	Date	£	s.	d.	PER HOUR	Date	£	s.	d.	PER HOUR
a	Original Value														
b	Production Value (comparative)														
c	Space Occupied														
d	Power Absorbed														
e	Depreciation & Insurance														
f	Interest														
g	Floor Space														
h	Power														
i	Jigs, Fixtures & Special Tools														
j	Loose Tools														
k	Supervision & Setting up														
l	Supplies														
m	Labourers														
n	Works Administration														
	TOTAL														

NOTE.—Description of expense may be further sub-divided to the greatest extent practicable for the purpose of giving the most accurate allocation of charges.

Fig. 1.—Sub-division of establishment charges.

which gives the hourly rate chargeable, hereafter referred to as an item of machine rate.

Particular note should be made of the term "productive hours," *i.e.*, the number of hours in which the machine is actually engaged on production, which is, of course, the great factor in determining the yearly percentage figure for depreciation and other charges to be described later. An explanatory example showing the high cost effect of non-productive or idle time machines will also be given, supporting the point made of supplying the production man with details of establishment charges.

(*f*) *Interest* on production value—item (*b*)—in the form of yearly percentage is also translated into an item of machine rate in the same way as item (*e*).

(*g*) *Floor space* (including operating space). This is charged to the machine rate in the form of rent for space occupied, which covers

the proportionate interest on capital expenditure, insurance, and depreciation of buildings, lighting, heating, etc.

The total area of the production departments is taken, and the total expenses, relating to those departments, are calculated into cost per square foot of space, so that every department bears its correct share of these expenses. The floor space occupied by machines is charged for directly at pence per working hour to the machine rate. Departmental space occupied by offices and general fixtures is further charged for in the proportionate hourly rate basis described in item (*k*).

(*h*) The *horse power* absorbed to run the machine under normal working is obtained from engine-room or power-house log sheet records, and it is assumed that engine-room expenses have been previously translated by the cost department into pence per horse-power hour. This, then, gives a definite item of machine rate.

(*i*) *Jigs, Fixtures, and Special Tools.*—The expense incurred for this item when necessary for a particular machine, or operation performed on a machine, is covered in the same way as described in items (*e*) and (*f*), when the operation is on a standard part or piece and recurring over a number of years.

In the case of expense incurred to perform the operation on a predetermined quantity of parts in a given period of time, the total expense is divided by the productive hours for this period, which gives the item of machine rate.

(*j*) *Loose Tools.*—General cost of tool room service, such as cutter grinding, tools and gauges, etc., common to many operations, is further added to the machine rate in proportionate departmental percentage, on the basis of productive hours of each department to the total productive hours of all departments. (Factored tools, etc., obtained by means of stores requisitions are dealt with under item (1) *q.v.*)

(*k*) *Supervision and Setting Up* may be classed under three headings :—

(i) *Direct Machine or Operation* supervision, as, for example, setter-up or charge-hand, whose time is devoted solely to a certain number of specified machines. This expense is divided by the added productive hours of all the machines for the same period, which gives this item of machine rate.

(ii) *Departmental* supervision. These expenses for each department are divided by the total productive hours of all machines in the department, for the same period, which gives the hourly machine rate item.

(iii) *General or Management* supervision. The total expenses are distributed over all departments proportionate to their productive hours, and the machine rate item is obtained by dividing the total expenses by the accumulated productive hours of all departments.

(*l*) *Supplies.*—The principal expenses under this heading are consumable stores which are a direct charge against the machine, and can be definitely traced by the *standing order number* system operating as follows :—

A predetermined departmental order number is used for time and supplies under various headings. When directly chargeable against a machine or operation the order number is prefaced by the machine

number, giving the direct expense which, divided by the productive hours of the machine for the same period, gives this item of machine rate.

Departmental expenses, traced by the same system of standing orders, are recovered in the same way as departmental supervision, *i.e.*, the expenses for a given period divided by the departmental productive hours for the same period give the machine rate item.

The total sum expended on supplies for service departments divided by the total productive hours of all departments gives the remaining item of machine rate against the heading "Supplies."

It is perhaps necessary to emphasise the advantage of a lengthy list of standing order numbers for the purpose of allocating establishment charges. The order number, of course, defines where the expense incurred must be debited, therefore a longer and more detailed list of order numbers results in a correspondingly increased accuracy for allocating establishment charges. In fig. 2 is shown an arrangement of standing order numbers for this purpose, which should be supplied to every department.

(*m*) *Labourers.*—The expense incurred for departmental labourers for a given period divided by the total productive hours of the department for the same period gives this machine rate item.

The expense incurred for labourers working in service departments for a given period is divided by the accumulated productive hours of all departments for the same period, which gives this item of machine rate.

(*n*) *Works Administration.*—This item embraces a large field of expenses which cannot be enumerated in standard form, since every factory organisation varies in detail to suit local conditions. The following paragraphs will, however, briefly cover the general expenses sufficiently to explain the principle outlined. The principal items under this heading are dealt with in the paragraphs which follow :—

(i) *Interest* on capital outlay or rent for all land and buildings, depreciation of buildings, repairs and maintenance of buildings, lighting and heating—the basis for allocating charges being space occupied :—

(*A*) by machines
(*B*) by departments
} plus service space.

(ii) *Machine floor space*—dealt with in item (*g*).

(iii) *Departmental space.*—It is assumed that the departments are not detached buildings, but are under one roof. The total area of each department, less productive machine space, in terms of expense per square foot, divided by the total production hours of all machines in the department, gives the hourly machine rate.

(iv) *Service space.*—This includes all expense not covered by items (i) and (ii), the sum of which is divided by the total productive hours of all departments, giving the hourly rate.

Rates and Taxes.—It is assumed that these are assessed on valuation scheduled under headings :—

(1) Machine valuation.
(2) Departmental valuation.
(3) Total valuation.

The expense can then be charged to the machine rate by the same method as floor space, *i.e.* :—

(1) Machine—direct charge.
(2) Departmental expense—less amount covered by (1) is divided by the total departmental productive hours.
(3) Total expenses not covered by (1) and (2) are divided by the accumulated productive hours of all departments.

Insurances.—State, fire, workmen's compensation, and employers' liability are similarly charged against operations—directly, departmentally, and remainder—not covered by the first two items.

Overtime Allowances.—The extra wages, such as time-and-a-quarter, time-and-a-half, etc., paid for overtime in the shops, should be regarded as an administration expense. The total sum for a given period, divided by the accumulative productive hours of all departments, gives the hourly machine rate item.

The sum total of items (*e*) to (*n*) gives the hourly machine rate, which figure or unit value should be carefully noted by the production men when laying out or processing operations for the machine shops.

A further example of the advantage to be gained by the production man in having before him the detailed items of machine rate is shown in the case of non-productive or idle time on machines. The production man is naturally attracted to the intensive multi-tool types of machine which produce the greater number of pieces per hour. The tendency is to install such a machine in the works even at a correspondingly higher price, in preference to a simple-tool machine of less capacity and lower cost, without carefully calculating what proportion of the total possible production hours the machine will be required to run in order to complete the output programme.

The points to be carefully noted in connection with idle time are fixed expenses, *i.e.*, those which occur whether the machine is working or not. The most important of these items are :—

(*e*) Depreciation and insurance.
(*f*) Interest on value of machine.
(*g*) Rent—for floor space occupied.
(*i*) Jigs, fixtures and special tools.

To illustrate an extreme case :—Two machines, Nos. 501 and 509, of equal production capacity, and each machine incurring expenses *e*, *f*, *g*, and *i*, £85 yearly.

Machine No. 501 actually works 1,700 hours.
Machine No. 509 actually works 425 hours.
Assume the total possible production hours = 1,800.

Then the hourly rate chargeable for items *e*, *f*, *g*, *i*, will be as follows :—

$$\text{Machine No. 501} \quad \frac{£85}{1{,}700 \text{ hours}} = 1/\text{- per hour.}$$

$$\text{Machine No. 509} \quad \frac{£85}{425 \text{ hours}} = 4/\text{- per hour.}$$

The detailed figures of expense could be further used as a guide to the production engineer in determining the type of machine tool to install when extensions of plant are contemplated.

Form No.

STANDING ORDERS FOR ESTABLISHMENT CHARGES.

	Reps. and Maint. of Buildings.	Reps. and Maint. of Plant.	Reps., Replacements, Addns. and Maint. of Loose Tools and Equipt.	Miscellaneous Time and Supplies.
Main Shop.				
Smithy	376	400	430	460
Turnery	375	401	431	461
Turret	375	402	432	462
Gear Cutting	375	403	433	463
Milling	375	404	434	464
Planing and Shaping	375	405	435	465
Fitting	375	406	436	466
Drilling	375	407	437	467
Tool Room	375	408	438	468
Hardening Shop	390	425	455	496
Grinding	375	409	439	469
Plant Repair Department	375	—	440	470
General Stores	380	414	444	474
Rough Stores	320	414	444	493
Inspection Department	375	426	453	494
Metallurgical Chemist	375	—	452	482
Experimental Department and Laboratory	382	427	454	484
Finished Part Stores	375	—	449	479
Jig and Tool Stores	393	—	458	501
Main Shafting	—	411	—	528
Motors—for Main Shafting	—	419	—	529
Belt Repairs and Oiling Shafting	—	—	—	478
Gas Compressor	—	—	—	490
New Tools for General Use	—	—	441	—
Repairing Tools	—	—	450	—
Engine or Motor Breakdown	—	—	—	483
Waiting (Idle Time)	—	—	—	487
Maintenance of Gas Service	—	—	—	490
Maintenance of Electric Lighting Service	—	—	—	491
Works Telephone Service	—	—	—	495
Athletic Club	—	—	—	522
Photography—Dark Room, &c.	374	—	372	503
Rectifying, Adjusting, &c., after despatch, under guarantee	—	—	—	504
Foundry	377	412	442	472
Pattern Shop	379	413	443	473
Patterns	511	420	512	513
Paint Shop	381	—	510	476
Engine House, Producer House and Battery Room	378	417	447	477

Fig. 2.—Arrangement of standing orders for establishment charges.

Form No.

STANDING ORDERS FOR ESTABLISHMENT CHARGES.

	Reps. and Maint. of Buildings.	Reps. and Maint. of Plant.	Reps., Replacements, Addns. and Maint. of Loose Tools and Equipt.	Miscellaneous Time and Supplies.
Main Shop.—Continued.				
Mess Room	385	415	445	475
First Aid Room	392	—	459	502
Motor Lorry Service	—	429	456	498
Garage	388	424	516	517
Packing	514	515	509	471
Despatch Office	383	—	—	485
Works Lavatory	384	—	—	485
Timekeeper and Watchman	—	—	—	485
Yard, Fencing, Gates, &c.	389	—	—	486
Drainage	391	—	—	521
Heating Boilers and Plant	386	421	451	481
Offices at Works.				
Works Manager	382	—	452	482
Production Engineer	382	—	358	359
Planning Department	382	—	457	500
Progress Department	382	—	356	357
Jig and Tool Drawing Office	382	—	354	355
Drawing Office	382	—	448	488
Time and Bonus Office	382	—	352	353
Cost Office	382	—	350	497
Commercial Offices.				
Managing Director	394	—	—	508
Sales Department and Advertising	394	—	—	506
Buying Department	394	—	—	520
Secretary and Accounts Department	394	—	—	499
Electric Lighting	—	—	—	505
Other Charges	—	—	—	521

Repairs and Maintenance of Buildings covers Repairs to Roof, Floor, Door, and Water Service.

Repairs and Maintenance of Plant covers Repairs and Maintenance of Machines and Countershafts. It is necessary to give Machine No. as well as Order No.

Repairs and Maintenance of Loose Tools and Equipment covers Repairs to Jigs and Tools, New Loose Tools and Equipment including Drills, Reamers, Taps, Files and Handles, Hammers, Chisels, Cutters, Lathe Tools, Hack Saws, Emery Wheels, Shovels, Buckets, Sieves and similar items.

Miscellaneous Time and Supplies covers Labourers' Time, Odd Jobs, Cleaning Machines Rag, Oil, Emery, Paraffin, Brushes, Brown Paper, String, Soap, &c.

Fig. 2.—*Continued.*

The examples below illustrate "idle time" as the determining factor in economic lay-out for different output programmes:—

(*A*) Where it does not pay to install an automatic or multi-tool machine in preference to a simple-tool machine.

(*B*) Where it does pay, *i.e.* in the case of greater number of parts required per yearly programme and correspondingly less idle time.

(*A*) Take the case of a required output, as per programme for one year, say, 900 pieces.

Total possible machine production hours = 1,800.

Assume that an auto multi-tool machine (*xx*) could produce the required output in 225 hours.

The fixed expenses, *e*, *f*, *g*, *i*, are £360 per year.

Then £360 divided by 225 = 32/- per hour.

Fluctuating expenses relative to actual working only are 6/- per hour—making a total machine rate of 38/- per hour.

Operator's wages = 1/6 per hour
Complete hourly rate = 39/6

Then $\frac{\text{number of hours} \times \text{rate}}{\text{number of pieces}}$ = cost each.

$$\frac{225 \times 39{\cdot}5}{900} = 9/10\tfrac{1}{2} \text{ each multi-tool cost.}$$

Now assume a less expensive simple-tool machine (*x*) which could produce the required output in 900 hours.

The fixed expenses £180 divided by 900 = 4/- per hour
Fluctuating expenses = 3/- ,,
Total machine rate = 7/- per hour
Operator's wages = 1/6 ,,
Complete hourly rate = 8/6

Thus $\frac{900 \times 8/6}{900}$ = each simple tool cost.

(*B*) The same machines used to produce a required output programme for one year—say 1,800 pieces.

Machine (*xx*) can produce required output in 450 hours.

Fixed expenses £360 divided by 450 = 16/- per hour
Fluctuating expenses = 6/- ,,
Operator's wages = 1/6 ,,
Complete hourly rate 23/6

Thus $\frac{450 \times 23/6}{1{,}800} = 5/10\tfrac{1}{2}$ each multi-tool cost.

Machine (*x*) can produce the required output in 1,800 hours.

Fixed expenses £180 divided × 1,800 = 2/- per hour
Fluctuating expenses = 3/- ,,
Operator's wages = 1/6 ,,
Total hourly rate 6/6

Thus $\frac{1{,}800 \times 6/6}{1{,}800}$ = 6/6 each simple tool cost.

It will be noted that the figures given have been chosen for ex-

planatory purposes, so that the calculation can be understood at a glance; it is not suggested that the proportions are an estimate of actual practice.

Establishment Charges—Fitting and Assembling Operations.—The expenses borne by the departments will be covered by items (*i*) to (*n*). All productive operators' hours should carry a fixed hourly rate which may be calculated on the same basis as machine rate item, *i.e.* :—

(1) Expenses directly chargeable against operation.

(2) Expenses directly chargeable against departments, the sum of which is divided by the total productive hours of the department to give the hourly rate item.

(3) The remaining expenses not covered by (1) and (2), the sum of which is divided by the accumulated productive hours of all departments to give the hourly rate item.

This principle will apply to all other production operations for which a machine is not specially employed to perform the operation.

Note.—As a number of expenses must of necessity be estimated owing to fluctuating factors—the varying purchase price of coal could be instanced—it is advisable to check cost accounts monthly, or at other suitable intervals as determined by the circumstances, to ascertain the extent to which productive hourly expense rate has absorbed actual expenses, and, if necessary, to adjust the expense rates in the form of a general percentage.

General Remarks on Establishment Charges.

The system outlined above has been set out for the purpose of illustrating an important point in connection with factors in production. It is not necessarily intended to represent an ideal accountancy lay-out, but is submitted with a view to assisting the accountancy expert in making the system for allocating establishment charges of practical use to the production man in his official capacity.

Furthermore, it is possible that the system propounded may not be applicable to every factory, but it is very probable that the function which it has been attempted to illustrate can be incorporated in any cost system.

Records Concerning Production Operations.

Minor forms used for costing purposes, such as stores requisitions, lay-out of operations, with bonus times allowed, may be passed over as generally understood, and the next important item to be dealt with is the system for recording the time spent and wages paid on operations, which justifies a special study, particularly with regard to :—

(1) Rejected parts (*i.e.*, parts which may be corrected by further operations).

(2) Parts actually scrapped.

(3) Operations which have necessitated extra time to produce owing to exceptional conditions.

It is necessary to record clearly the reason for the rejection or scrapping of the parts. The production engineer or shop superintendent will realise the thousand and one different factors which may individually or collectively be the real cause of these three incidents

in production, and of the consequent high spot in production cost. The cost man, however, has to rely solely on paper records, and since excessive cost usually means that someone has blundered, and must, therefore, in shop parlance, "be brought on the carpet," it is advisable that the true facts be fully recorded.

Time recorder system of clock cards which carry the information relating to manufacturing operations are now generally accepted as being most efficient, whether the method of payment be day work,

Front view of card

THIS SIDE OUT

Man's No 582 Date 3rd Mar 1921

GOOD	REPAIRABLE	MAN'S SCRAP	MAT. SCRAP	TOTAL GOOD	
42	2	1	5	44	R. Mason Insp.
44	1	1			Foreman's Sig. J.L.R

State definite reason for above

Repairable .125" Large on Dia (one turn of micrometer barrel) Returned for correction

Man's scrap Turned too short on overall length

Material scrap Blow-holes in Internal bore

Authority P. Vincent

"Special allowance, or alteration, due to exceptional conditions" Allow an extra 10 mins. each on 5 material scrap.

Reason for above Part by machined before Blow-holes are found.

Charge against Buying Dept.

Authority P. Vincent

Only CLOCK records will be recognised

A man may not clock off this ticket unless he has obtained a further ticket with which to clock on

No man is allowed to remove this card from Rack except for the purpose of recording his time.

BY ORDER ____

_____ Ltd.

Workman's Signature G Pearson.

Back view of card

Man's Name G. Pearson Man's No 582

PREM. BONUS TICKET

Order No R 289c No B - 4362

Batch No 3 Part No R.289

Description 50 Sliding Bush Castings

Date Issued March 3rd /21. Cont'n Tickets —

DAY		ON	OFF	ON	OFF	TOTALS HOURS	TOTALS MINS
W	AM	7-39 MAR 4th	12-31 MAR 4			8	30
	PM	1-31 MAR 4	5-33 MAR 4				
T	AM	11-2 MAR 5	12 0 MAR 5			1	0
	PM						
F	AM						
	PM						
S	AM						
	PM						
S	AM						
	PM						
M	AM						
	PM						
T	AM						
	PM						

Allow 15 mins each + 3hrs setting Ref No 5289

Clerk's Initial J H

	HOURS	MINS
Total Time Allowed	14	50
Total Time Taken	9	30
Time Saved ~~Lost~~	5	20

Mc. No 407

OP SEQUENCE No 1

Operation Turn 2.375 Dia. face flange & front to length. bore & ream Int. dia comp

Fig. 3.—Example of premium bonus ticket.

piecework, or premium bonus. An opinion will not be passed here on the respective merits of these, as the question might readily furnish the subject for a future paper. It is desired, however, to give an example of a clock card with provision made for the point previously emphasised as to the necessity for defining excessive cost for the benefit of the cost department.

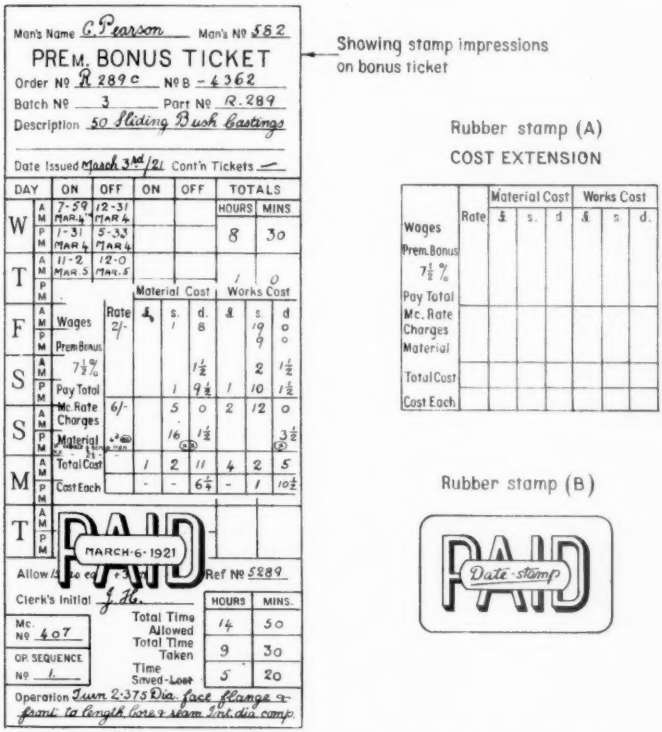
Premium Bonus Ticket.

The function of the premium bonus ticket, illustrated in fig. 3, is almost self-explanatory, and in fig. 4 is presented a hypothetical case showing how unusual operation cost may be dissected, under the following headings :—

(1) *Operator's scrap*—chargeable against works cost.

(2) *Defective material*—which is charged against material cost. The reason for scrap is also recorded.

A bonus ticket is issued to the operator with the batch of work,



Showing stamp impressions on bonus ticket

Rubber stamp (A)

COST EXTENSION

	Rate	Material Cost £	s.	d	Works Cost £	s.	d.
Wages							
Prem. Bonus 7½ %							
Pay Total							
Mc. Rate Charges							
Material							
Total Cost							
Cost Each							

Rubber stamp (B)

Fig. 3.—Example of premium bonus ticket.—*Continued.*

and accompanies the work to the inspection department immediately the operation is completed.

This bonus ticket then passes from the inspection department to the progress department adjoining, where it is clock date-stamped, and the information required by the progress department is recorded. The ticket is then put into the cost office hourly collection box. Strict

rules should be made to ensure that there is no unnecessary delay in dealing with these tickets. It will be seen that the last clocking made by the operator, plus the necessary time for transport, checked by inspection department, gives the approximate time that the work is in the hands of the inspection department. The clock stamp checks the receipt of the ticket into the progress department, and

FORM Nº _____

DISSECTION OF SCRAP COST

COST OFFICE

Dept. _____ Week Ending _____

Clock Nº	Operator's Name	Bonus Ticket Nº	Value of Scap £	s.	d.

Form Nº ____ FROM COST OFFICE TO BUYING DEPT.

WEEKLY RECORD

MATERIALS USED & COST OF SCRAP

Week Ending _____

Supplier	Symbol Nº	Total value Mat. used £	s.	d.	Cost of Scrap £	s.	d.	Percentage of Scrap	Refer to Bonus ticket Nº

Fig. 4.—Example of dissection of scrap costs.

the hourly collection made by the cost department puts the information into their hands with the least possible delay. In a later paragraph the importance of this procedure is explained.

The bonus ticket is extended by the cost department, as shown by the rubber stamp impression, and the operator's wages informa-

tion transferred to wages book; the bonus ticket is then stamped "Paid," as shown in fig. 3, which stamp also indicates that the ticket has been dealt with in respect of wages.

The final records are then transferred to the batch cost sheet, the tickets being filed departmentally in numerical order. It will

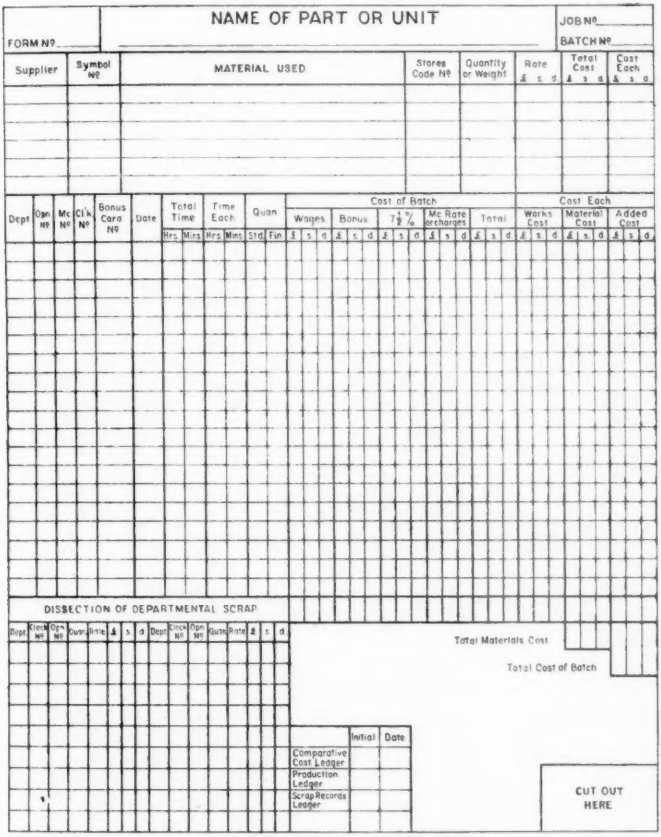


Fig. 5.—Batch cost sheet.

be noted that the bonus ticket has been designed to record the maximum of information and to avoid duplication of forms and excessive clerical cost. For the purpose of quickly locating the tickets, every department has a differently coloured ticket, and the continuation tickets, day work tickets, etc., are further distinguished by a contrasting colour at the left-hand top corner.

Batch Cost Sheet.

A method of recording works cost and material cost in batch quantities is illustrated in fig. 5. A programme of output to cover a period of, say, six or twelve months is decided upon, representing a given quantity of a certain type or types of finished product, each

FORM Nº _____

FROM COST OFFICE TO — { WORKS MANAGER / PRODUCTION ENGINEER

WEEKLY PRODUCTION RECORD AND COST OF SCRAPPED WORK

Week ending _____

DEPARTMENT	Production value at Works cost £	s.	d.	Cost of Scrap £	s.	d.	Scrap Percentage
TOTALS							
Signed				General scrap Percentage			
Date							

Individual totals for each operator are given on seperate departmental forms attached.

Fig. 6.—An example of departmental scrap record.

comprising a number of component parts, one or more of each part being required to assemble or fit up the complete unit.

The total quantities of every component required to complete the programme of output, including estimated extras to cover scrap, are divided into weekly or monthly batches, such as will

ensure an even flow of parts into the fitting and assembling departments. Every batch carries its numerical symbol, which is shown at the top of the batch cost sheet, so that comparative cost of the succeeding batches is easily traceable.

It will be seen that the batch sheet is carefully designed to record, as completely as possible, the details of cost as transferred from the bonus tickets, in addition to establishment charges and material, so that exceptional cost under any of the headings can be noted immediately at any stage of the operations.

In this connection, special importance is attached to obviating delay in passing the bonus tickets through the works to the cost office, since the methods outlined render it a simple matter to show the cost of any operation within twenty-four hours of its having been performed by the operator. In the case of exceptional costs,

FORM N°_____ FROM COST OFFICE TO —— {WORKS MANAGER / PRODUCTION ENGINEER / BUYING DEPT.

YOUR ATTENTION IS CALLED TO EXCEPTIONAL COST ON THE FOLLOWING OPERATION

Part N° _____ Name of Part _____ Material _____

Operation N° _____ Description of operation _____

Time allowed each _____ Hrs. _____ Mins.

Dept	Ope N°	Mc & Fix N°	Bonus Card N°	Date	Quan.	Total Time	Time Each	Cost of Batch: Wages & Bonus	Cost of Batch: Mc Rate & Charges	Cost of Batch: Material	Cost Each: Works Cost	Cost Each: Material Cost	Mat Symbol N°	REMARKS Note re abnormal conditions if any
					STD FIN.	HRS. MINS	HRS. MINS	£ s d	£ s d	£ s d	£ s d	£ s d		

PREVIOUS RECORDS OF SAME OPERATION ARE GIVEN BELOW FOR COMPARISON

Date _____ Signed _____

Fig. 7.—Card for indicating abnormal costs.

the records of these can be sent to the persons directly concerned, so that they can take immediate advantage of the information. Production men will readily appreciate the value of this.

The figures relating to cost of scrap are extended by taking the added sum of works cost and material cost each to the stage reached and deducting the current value for the scrapped material, so that a component scrapped in, say, the sixth operation is charged with the added cost of the five previous operations, in addition to the cost of the sixth operation.

When transferred to their own ledger the scrap records, as shown in fig. 6, provide the figures relating to departmental scrap, which are sent to the works manager, production engineer, and buying department—as shown in figs. 4, 5, and 6. This, in conjunction with the departmental production figures for the same period, provides the data for departmental efficiency charts.

In fig. 7 is illustrated a standard form used by the cost department for notifying the works manager, production engineer, and

buying department of exceptional cost as affecting the respective departments.

The Outlined System in Practice.

The author's experience of the value of such a system will be recounted in connection with two methods of performing a machine shop operation, which may be of interest to production men. It will illustrate the advantage obtained from cost office records, closely following a shop incident, and will further emphasise the points made regarding establishment charges as an important factor in

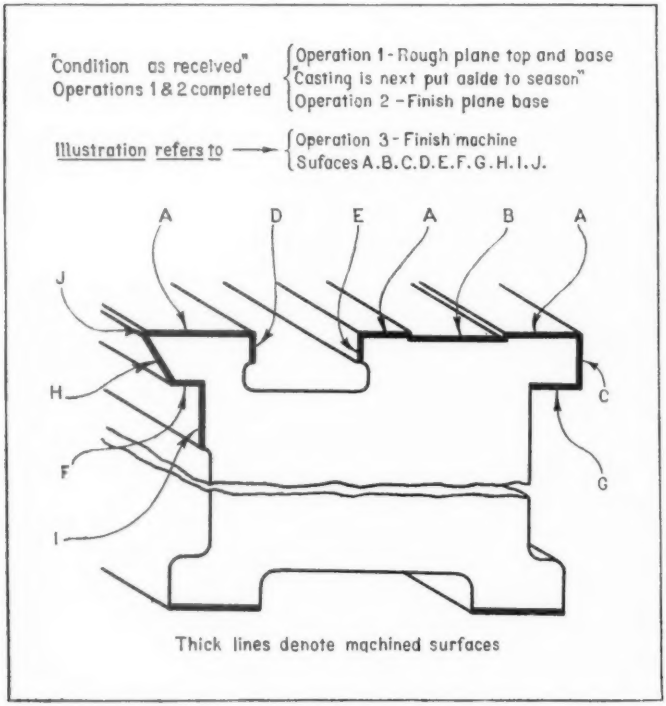


Fig. 8.—A sample casting to be machined.

economic production. A machining operation on an urgent batch of castings was involved. The milling machine on which the operation was usually performed being under repair, it was necessary to put the job on a planing machine. The result was that an exceptional cost form was sent without delay to the works by the cost department, showing the figures relating to both methods.

The actual facts are given below.

Planing and Milling.—Comparative costs of an operation performed by each method.

In fig. 8 is illustrated the section of a casting, and the operation referred to is the machining of surfaces A, B, C, D, E, F, G, H,

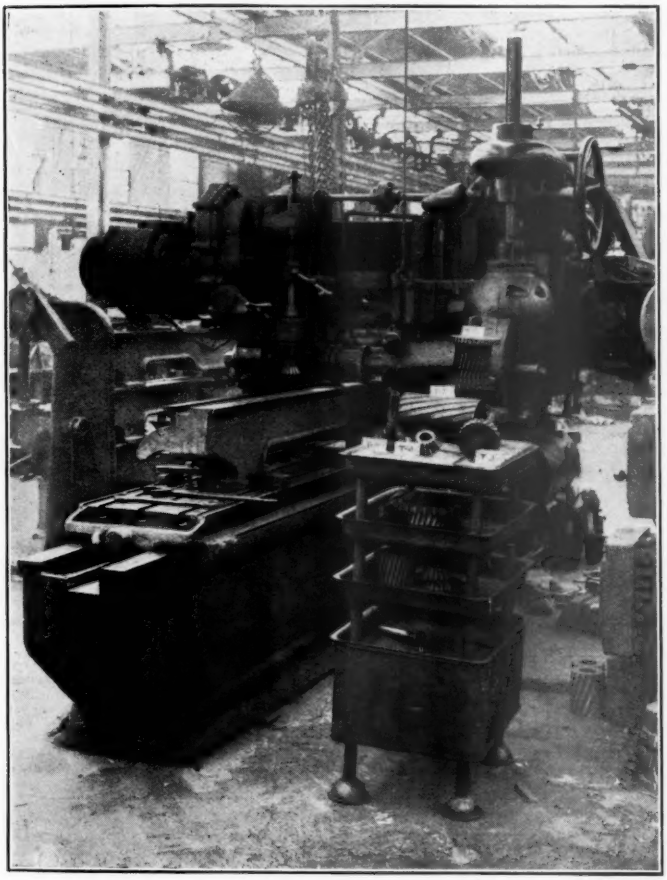


Fig. 9.—Plano-miller layout and cutter equipment.

I and J. Both the milling and the planing operations were performed with high-speed tools, and special gauges for checking angles, etc., were provided. Cutting speeds and feeds are predetermined

under test conditions, so that equal efficiency of working conditions may be assumed:—

First Method.—Milling.—The operation is laid out for milling

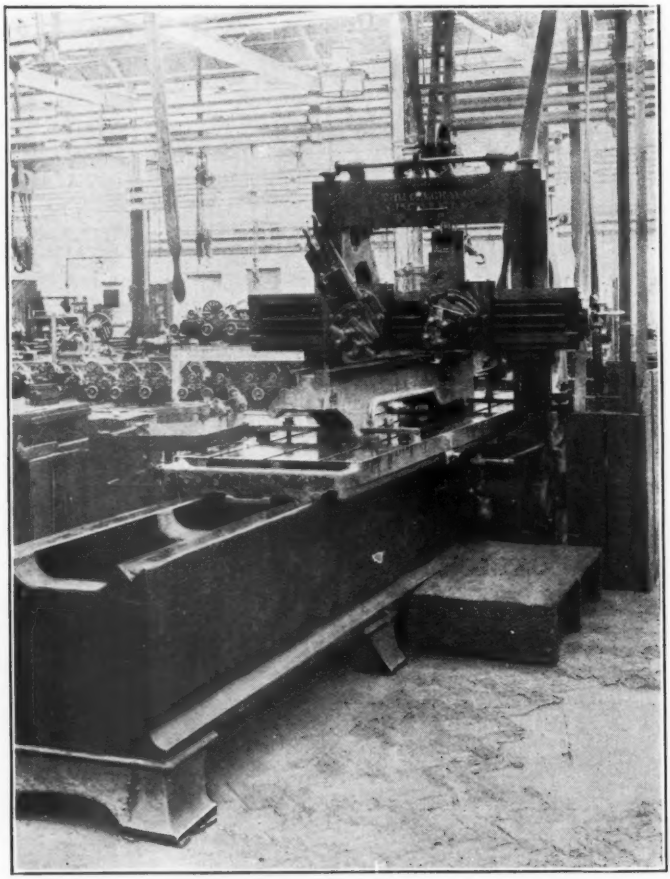


Fig. 10.—Planer set-up.

complete, as illustrated in fig. 9. It will be seen that the machine is of the plano-miller type, with both horizontal and vertical spindles, therefore the casting can be completely machined on all surfaces with one setting only, thus ensuring correct alignment.

The machining of the different surfaces was performed in the following sequence :—

(1) Gang mill surfaces, A, B, C, D, E, and J, leaving 1/16in. on surface A for finishing cut in final operation.
(2) Mill (vertical spindle), surface G.
(3) Mill (vertical spindle), surfaces F and I.
(4) Mill (vertical spindle), surface H.
(5) Mill (horizontal spindle, finishing cut), surface A.

Second Method.—Planing.—The capacity of the planing machine illustrated in fig. 10 was about equal to that of the milling machine. The casting was located similarly, all the surfaces being machined with one setting only, and no special tools were required.

One of the tool slides was provided with a taper locating pin for setting to the exact angle for surface H—to obviate the difficulty of setting accurately to the graduated lines. The machining of the surfaces was performed in the following sequence :—

	FIRST METHOD		SECOND METHOD	
	Units of Time	Units of Money	Units of Time	Units of Money
Time taken				
Wages paid	11		12	
Establishment charges		88		96
		332		176
TOTAL COST		420		272

Fig. 11.—Chart of units of time and money.

(1) Plane (using two heads), surfaces A, B, I, and J.
(2) Plane (using two heads), surfaces C and D.
(3) Plane (using two heads), surfaces E and F.
(4) Plane (using two heads), surfaces H and G.
(5) Plane (finishing cut), surface A.

In fig. 11 are shown in units of time and units of money the true comparison between the two methods of machining.

It will be seen that the planing method was the more economical although milling was the quicker process, since the planing machine could perform the operation on the same quantity of castings for £272, while the milling method would cost £420 (assuming a money unit=£1). The "high spots" of cost are shown in fig. 12, which gives the detailed items of machine rate.

The milling machine was the more expensive to purchase, and absorbed a greater horse-power than the planer. In the case of the milling machine, the cost of maintenance for the complete sets of milling cutters was the outstanding item, since it was, of course, necessary to have three complete sets at all times: one set in use,

one set being resharpened, and a spare set in stock in case of breakage.

Concluding Remarks.

The various points in the system outlined have been made with the desire for a better understanding and a practical co-operation between works and offices. The author's experience, which he believes is shared by many other engineers in executive positions, points to the belief that this co-operation is rarely attained in practice. Blame can hardly be attached to either of the

PLANT RECORD	Milling Mc. № 509 Date 10-3-15		Planing Mc. № 403 Date 28-2-15	
	Units of Money		Units of Money	
Original Value	7680		5376	
Production Value (comparative)	9600		6720	
Space Occupied	160 sq.ft.		178 sq.ft.	
Power Absorbed	15 H.P.		10 H.P.	
DESCRIPTION OF EXPENSE	Yearly cost	Per hour	Yearly cost	Per hour
Depreciation & Insurance	960	35	672	24
Interest	690	25	570	18
Floor Space	148	6	163	7
Power	1440	45	960	30
Jigs, Fixtures, & Special Tools	3035	102	85	7
Loose Tools	1296	63	825	36
Supervision & Setting up	192	9	192	9
Supplies	19	1	19	1
Labourers	330	14	330	14
Works Administration	690	32	672	30
TOTAL	8800	332	4488	176

Fig. 12.—Record showing detailed items of machine rate.

sections named, the trouble being, in all probability, due to functional circumstances.

There is perhaps a tendency in each department to guard over-zealously its own particular side of the business. By co-operation in drafting the system, the business problems as a whole would be studied, resulting in a better mutual understanding. The best way to appreciate the other fellow's point of view is to understand his difficulties.

The two sections, and, in fact, all sections, incur expenses which are covered by establishment charges. This question has been dealt with at length from the point of view that, to be successful in business, not only must the direct production expenses which cannot be justified be eliminated, but also all such expenses.

While the subject has been treated from the works aspect, it is possible that the benefit derived by the production engineer from a closer acquaintance of detail costing might also apply, in principle, to the heads of all the departments in a business, particularly in the case of firms who manufacture several types of product, and in quantities varying from dozens to thousands. When dealing with large quantities the expense of an elaborate lay-out may more than pay for itself, but if applied to small quantities the overhead charges might kill any chance of success, even before the manufacturing operations were performed. If records of expense up to date could be supplied to departmental heads in the early stages, it would enable them to make the necessary provision for expenditure in proportion to results to be achieved.

The endeavour has been to effect this object when formulating the above system of representing costs, which system, it is believed, can be modified to suit any factory. Finally, an opportunity of testing such a system has been afforded the author in his business connection with Messrs. Drummond Brothers, where it has certainly proved very successful. In this connection, mention may be made of Mr. Millard, the head of the firm's cost department, to whom credit is due for designing certain portions of several of the figures which have been given.

Being responsible for works production, the author can fully appreciate the valuable assistance to be derived from an up-to-date cost department which is actively co-operating with the works.

THE DISCUSSION.

MR. BELL (London), in opening the discussion, congratulated the author upon having successfully developed such an elaborate costing system as had been outlined. His own experience had been that the costing department was the most difficult one to co-operate with in the shops. In fact, on two occasions the accountancy end of the costing system had entirely fallen through, and he, as works manager, had had to run the costing department actually in the works. There was, of course, the question from which end the costing system should be run. The ignorance of the accountant of works arrangement was, in his opinion, very much greater than the ignorance of the works manager of accountancy, and costing systems emanating from and actually run by the works, so far as his experience had gone, had been much more valuable than costing systems originating in and worked by the accountancy section. The accountancy section insisted upon very minute detail, which often cost far more to collect than it was worth, so that it became very much a problem as to where the costing system should start. He thought that it should start from the works, and he had run two quite successfully on those lines.

The allocation of all the overheads was always a highly debatable point. He had once tried to allocate to each machine its own particular overheads in respect of power, floor space, etc., but he had found at that time that the difficulties in the way were enormous, and he was not able to do it. Floor space was an extremely important matter, and the case of a firm with an excellent reputation for its mass production methods was cited, where it was the practice to insist upon the minimum of floor space for each machine installed. He admitted a distinct liking for a simple system, as a complex system was apt to be costly.

He would like to know the author's views as to the cost of running such a system as indicated in the paper. In his own experience, the cost of running an elaborate system was so high that the overhead cost necessitated by the costing department was excessive, compared with the savings effected.

He was particularly interested in the author's remarks as to the education of an engineer in matters relating to costing and organising, as distinct from the actual technical, designing or machining part of the works. That was a point which deserved very much more attention in our technical schools and colleges than it had at present received. For some years he had been a lecturer on general engineering subjects, and one of the most enjoyable parts of his work was the development of a series of lectures on problems affecting general organisation, estimating, costing, etc. It would be found that many of the young fellows who came from engineering colleges into a works had an excellent knowledge of mathematics,

mechanics, machine tools, etc., but their knowledge of works procedure was very slight, and as we looked to those young men for our future engineers, this was a matter of which the technical colleges should take greater notice.

He did not think that the author was quite correct in his statement that the production man was rather apt to turn unduly to the automatic machine as against the simple operation machine. His experience had been that for certain classes of work the automatic machine was pre-eminent, without doubt, but where operations could be split up and batches of simple machines used, employing simple labour, then it was better to use single-purpose machines. In deciding a point of that description the production engineer should have a sufficient knowledge of the allocation of overhead charges to know that a £2,000 machine would mean an abnormal overhead charge on the cost of the piece produced if there were an insufficient number to give him his proper works cost for that part. The bulk of the production engineers he had met would certainly take that point into account before recommending the installation of a very complicated and costly machine as against a simple one. It may be that sometimes large batches of articles had to be produced very quickly, and although these batches only came round periodically perhaps, an automatic machine was often warranted in such a case, although there were still overhead charges, even when the machine was idle. The articles had to be produced rapidly, and this could be done by labour diverted from other machines. Therefore, it was obvious that a production engineer should arrange his plant in such a manner as to be prepared for such a contingency.

Mr. R. Waring-Brown (Coventry) said he believed it was fully realised that a system of costing must depend on the nature of the works and the product. For instance, it was quite feasible that a system which would be satisfactory for a works producing lathes or machine tools would not be eminently satisfactory for a factory producing motor cars.

With regard to co-ordination in a works, he took rather a different view of the position of a production engineer in a factory from that of the author. As a rule the person whom the author called a production man looked at his system entirely from an academic standpoint, instead of a viewpoint which would be the outcome of a shop training, and the trouble with the production engineer in this country was that his status was not what it should be. The production engineer in America held a very much better position in regard to administration than was the case here. As a matter of fact, it was believed that he ranked above a works manager, so that he had an opportunity of thoroughly investigating a system of co-ordination, which was frequently denied to the man who in this country was designated a production engineer—probably a glorified progress clerk.

With regard to education on matters of works administration, in America they had a college a portion of which was entirely devoted to industrial engineering, and the professor there had specialised in works administration. He (Mr. Waring-Brown) had spoken to one or two engineering professors in the Midlands, asking them if they could not incorporate some such ideas in their courses in the future, but he was afraid he had not created very much enthusiasm. He was quite sure that education in that direction would do a great

deal of good, because at the present time it was just as easy to over-systematise as to under-systematise, and a proper knowledge of industrial engineering would help to rectify that.

Mr. E. W. Fairbrother (London) said that one had to be careful in tackling the question of cost accounts to differentiate clearly between economic production and works costing. He was afraid the author had rather confused them. The costing department required figures in bulk. Economic production was a vastly different thing, however, and the cards dealing with that should be kept in the works, so that the total figures could be given to the costing department in bulk for any given period.

The author had endeavoured to bring out what was now generally understood as the hourly burden system of costing. His own difficulty had been in trying to arrive at a suitable economic rate of machine hours. In establishing this system one had to assume that a machine was in operation for a certain number of hours per year, and unless one could do that the system would prove ineffective in the long run.

The President said he entirely disagreed with the method of calculation the author had demonstrated for arriving at a true cost. His definition of cost was that which was expended in making a certain article. If they purchased a machine tool and installed it in a works it certainly had a capital value, it carried certain interest, occupied a certain amount of floor space, etc., but one must stop somewhere. The machine No. 501, indicated in the paper, carried £85 establishment charges; machine No. 509 also carried £85 a year. Those sums they had to pay, whether they used the machines or not, and it did not appear to him that because one machine was kept more fully occupied it was cheaper than the other. What one had to do to make money out of machine No. 509 was to get more hours out of it. He did not agree with the deduction that the operation of that machine cost 4s. per hour. The operating of the machines was the same, they were of the same capital value and the same productive power, and the trouble was that there was not sufficient work. If one carried that a step further to-day, when works were only running perhaps one, two or three days a week, it would be seen that by that fact alone costs had gone up. The market would not absorb the goods because it had not the money. If that £85 were divided in each case by 1,800 hours, then one would get the true hourly rate for the machines.

With regard to the premium bonus time card, which the author had illustrated, it seemed that an endeavour had been made to get too much on it, and that the data would be better and more economically recorded by using separate pieces of paper. In his management he had never allowed on any bonus time card, or piecework job card, or daywork job card, the notice that was printed on the card illustrated by the author to the effect that a man might not clock-off that card unless he had obtained a further ticket on which he could clock-on. His (the President's) rule had been that the moment a man had finished work he must clock-off the card. If he had not another job, waiting-time must be booked, which was sometimes very important.

As to the cost office sending records into the works, he had found that the only thing it was necessary or desirable to do was to send records of their failings. If it were estimated that a job would cost

6d., and it actually cost 5d., everybody was pleased, and no more need be said about it; but if a job estimated to cost 6d. had actually cost 1s., then a record of that should be sent. One way in which he dealt with that side of the question was never to alter a piecework price, and never to alter a bonus rate, unless it was altered for all time, and if one were making an article priced at 6d. per gross, but which it was found would cost a good deal more, there would be an allowance of 1s. 6d., or whatever the figure might be, which allowance had to be passed by an official. That did not interfere with the cost at all. If anybody in the costing or any other department thought that allowance should not have been made, then it could be reported to the management and dealt with separately, and not introduced into the ordinary routine of the business.

In concluding his remarks, the President proposed a vote of thanks to Mr. Hales for his paper, which was carried with acclamation.

Mr. A. Butler (London), dealing with the premium bonus card illustrated by the author, said that he also did not agree with the rule as to not clocking-off a card until another card was obtained. He was rather doubtful about the method of using the bonus card. He understood that the card moved along with the work at the completion of each operation. It had been his experience that when a card was moved from its rack it generally went for all time. Further, he would like to know how the author dealt with a job which was continuously running. They did not want to send the card along every night, but they did want to send the work along. Then, again, they must move the bonus ticket some time just previous to the end of the week. He did not agree with so much information being stamped on the clock card, but that was one of the things which had to be decided by the nature of the work.

The cost office, he thought, should be run by the works side, because the information was most needed by the works. The accounting department was not really interested in how the costs were arrived at, but the works side was naturally concerned as to whether they had machines standing idle, thus increasing costs, or whether there was a large amount of scrap. He rather wondered, however, what effect it would have upon the works manager's department if a record of scrap of all the jobs that went wrong were presented to that department. There must be a limit, and unless a fair percentage was decided upon the works manager would receive a great deal of superfluous matter.

The idle time of a machine, he thought, ought not to be added on to the cost. After all, it had nothing to do with the production engineer in a good many cases whether there was too much plant in a factory or not; unfortunately, that official had not a sufficient voice in the matter—up to now at least. Idle time should come under the heading of overhead charges.

Mr. B. C. Olver (Derby) said he thought the author was correct in the method he had illustrated for arriving at costs. It was true that both machines, Nos. 501 and 509, were costing £85 a year, but after all, the idea of a costing system was to recover costs, and the only way to get these back was on the article produced. He could not see how they could recover expenses without putting them on the machine hours, if they were using the machine-hour rate.

A point which was not made quite clear in the paper was the

question of scrap. For instance, probably a casting might be defective through no fault of the moulder, and the firm would have to pay him to cast another. How should that scrap be dealt with? Should it be charged to a particular batch of castings, or should it be entered into a sort of general rejected materials account, or debited to overhead charges? Of course, it was entirely a matter for the management as to how far they were prepared to go with a costing system. They could fit a costing system into a works, but could not fit a works into a costing system. The system described in the paper was a very elaborate one, and he doubted whether it could be generally adopted without affecting the works. It was all right when starting a new works, but he doubted very much whether it would pay the majority of firms to put in such an elaborate system.

With regard to the costing being under the control of the works, this would bring about closer co-operation with the management. At the same time, while close co-operation was essential, it was advisable that the costing office should be under the administration of the accountant. The figures should always be accessible to the management. The accountant was a sort of Chancellor of the Exchequer, and should have the final word.

Mr. Hales, in replying to the discussion, thanked everyone present for the manner in which they had received his paper, which he considered amply justified his work.

In replying to Mr. Bell on the point as to who should be responsible for running the costing department, attention would be drawn to the example of Standing Orders which had been shown. It would be noted that the cost office was grouped with the works offices, where it was considered to be generally more convenient than if located with the commercial offices isolated from the works. The author was decidedly of the opinion that the costing side of the business should be controlled by the accountants alone. The works should have access to all the figures which directly concerned production, but there were a great many items of expense which must of necessity pass through the hands of the accounts department which were really of no interest to the works man. He (Mr. Hales) as a works man could not afford the time necessary efficiently to supervise the costing, and in any case he considered it preferable for a specialist to control any particular section of the business, whether the manufacturing or the accountancy side.

There appeared to be a number of production men present, and he rather thought that each one was inclined, so to speak, to "support his own side," that is, production officials were apt to attempt to control the office side of the business, whilst the officials on the office side would probably err in a similar way. He would not like to express an opinion as to which side of the business had the greater knowledge of the duties for which the other side was responsible.

Mr. Bell had mentioned that sometimes large batches of articles had to be produced rapidly at certain periods of a year. His experience had been that large batches of articles that were suitable for an automatic machine were rarely behindhand in an output programme. He usually found that the tendency in the works was for everyone concerned quickly to get ahead with large quantities, since once the machines were set up the operators were of little trouble to their foremen. In aero-engine and motor car manufacture

such items as valve stems or crankcase studs were rarely tardy, but the crankcase itself or the crankshaft, for instance, which necessitated a lengthy series of operations, usually unsuitable to multi-tool methods, were the items which hung up the output programme.

He was sorry that a number of speakers seemed to have formed the opinion that the system outlined was expensive. He could assure them that it was not so, and he would be pleased to give Mr. Bell personally, if he so desired, actual figures showing cost percentage of running such a system. He was quite sure that Mr. Bell or anyone else would be astonished at the low figure of the cost department expenses.

The question of waiting time had been raised, and it had been mentioned that if the machines were waiting the operator could go on another machine. That meant that machines were waiting all the time—if it were not one machine it was another. The point he wished to emphasise was that when a machine was standing there were constant expenses accruing which had to be paid, and everyone should fully realise what these expenses were.

Mr. Waring-Brown had mentioned the status of the production engineer. He himself had purposely used the term "production man" in the paper instead of "production engineer" to avoid misunderstanding as regards status. A production engineer's status had not been and could not be clearly defined. The term "production man" would mean in some cases the works manager, works superintendent or production engineer, and he had particularly mentioned that the man referred to must have a first-class practical and technical knowledge of engineering, and not merely an academic one.

Mr. Fairbrother apparently supported the opinion that the manufacturing side of costing should be done by the works officials. His own opinion was that this would be likely to cause confusion, since it would be difficult to draw the dividing line between the function of the works costing records and the records dealt with by the accounts department. Further, the works had not sufficient figures to enable them to draft a proper costing system; for instance, the capital outlay on machinery, tools, etc., which directly affected works cost.

The author had found no difficulty in arriving at machine-hour rates. He could not, however, understand the difficulty unless the works records and records kept by the accounts department were investigated together. In dealing with an output programme his practice was to take the whole of the machines in the departments and allocate the operations to the machines, so that it was not difficult to estimate in advance the approximate hours that any machine would be working during a given period.

The President had stated that his definition of cost was what was expended in making a certain article. The author had endeavoured to show the importance of installing machines suitable to a programme of output, so that the expenses incurred due to their installation would be recovered from the product obtained. The method of installing expensive machines, which may or may not be fully justified at a later date, represents the blank cheque principle, which might be comfortable but decidedly too risky for general practice.

The President had suggested that the true hourly rate should be obtained by dividing the total constant expense by the total possible production hours of the machine regardless of whether it actually

worked or not, in which case, since it would be necessary to recover the expense, the works as a whole would be debited with the account and the actual cause would in effect be obscure.

With regard to the installation of multi-tool machines, to put the case simply, a machine should only be installed when it would pay for itself. As to the programme of work for a machine when installed, one could take an estimated programme over ten years if desired, and spread the cost of the machine over the same period, the length of time being immaterial so long as the expense was actually recovered. His point was that the expense must be recovered, no matter what the length of the programme. If a machine had abnormal idle time, his opinion was that it was better out of the shop, because it was occupying valuable space.

In replying to the President and Mr. Butler regarding the note on the bonus ticket to the effect that a man must not clock-off one ticket until another ticket had been obtained, that warning was for the purpose of preventing a man clocking-off a bonus ticket connected with an operation prior to the actual completion of the job, which would then record a greater time saved than was the actual case. That was not an uncommon method of petty cheating which the author had experienced, and had usually been practised when the succeeding operation happened to be a daywork job or the operator had a waiting period. The time on daywork jobs, or waiting time, is recorded on a similar ticket to the bonus ticket, thus accounting for all factory hours. When an operation is completed the work is immediately removed to the inspection department accompanied by its own ticket, so that there is little chance for the operator to make incorrect clockings. He did not consider it preferable to put the information on two cards instead of one. His experience in this connection was that the more one multiplied the number of forms used, the more trouble it was to get any information relating to them, and the one card was the cheaper method. If one lost a bonus ticket a record of the time a man had taken was lost. One could not keep two records in any case, and certainly if the tickets were filed away they were as good a record as any other.

Answering Mr. Butler's question as to how to deal with a running job, the author said he had provided for that in his paper. It was there suggested that whatever the programme, the operations should be divided into suitable batches, extending over one or two weeks, or any other period, suitable for keeping the departments fully occupied. It did not matter if a man had two or more bonus tickets in a week; the batch quantities might be split up sufficiently small to suit the circumstances.

COMMUNICATION.

Mr. Hales is to be congratulated upon the excellent manner in which he has detailed the salient features of a reliable and effective costing system.

The method of working out the machine-rate is simple, but his suggestion for allowing idle time in the machines is not very clear. Does he really mean that if a certain machine works at half-capacity only it must be charged at double the rate it would otherwise bear in respect of depreciation, interest, rent, and tools? Possibly he is referring to special single-purpose machines. If a shop be running light, the result would be seen in very excessive costs, and the tendency would be to discourage rather than encourage incoming work, which is so much needed in the circumstances. If stock were made under these conditions the pieces so produced would have an entirely unmarketable value.

In the writer's opinion, there should be a fixed average percentage of possible working hours, and no other account should be taken of idle hours in fixing the costs. The difference between the additional cost and the normal cost (which is aways usefully apparent) should be charged as a selling expense.

Generally speaking, the machine-rate system is ideally applicable only to certain classes of businesses. Machine-tool work may be instanced as one of them, but not so motor-car work. The machine-rate system is usually elaborate, expensive, and easily rendered obsolete by plant extension or reduction. Alternatively, it can be made simple, but it is then ineffective and almost valueless. This will be influenced largely by the variety of types of machines in the works, and group rates are then a practicable variation.

Cost systems and accountancy methods would appear to have a continuous trend toward elaboration, and it is a matter for nicety of judgment as to where the dividing line should be drawn. Mr. Hales has, it would seem, effectively grasped this.

He further emphasises the importance of the costing system bearing a relation to the production man. What is a costing system for? It certainly is not put into a factory because it is a conventional thing, but on account of its utility. The cost accountants, who are generally non-technical men, use the figures for regulating the financial side only of the business, but this can easily be done without the need of a detail cost system, percentaging establishment charges, or elaborate groups of figures.

Unfortunately, there is usually a gap between accountancy and costing which is deplorable, and leads to innumerable errors. Surely a cost and accountancy system is the recognised tool of the works manager, and one that he will employ more than any other in his work. If he has the cost department properly organised and in thorough working order, it will give him instantly a direct "Yes" or "No" to every administrative problem that he is likely to

encounter. One thing is lacking in the paper, however, to enable this condition tc be entirely fulfilled—that is, that there is no comparison basis suggested. Figures are meaningless without it. Therefore, every job should be theoretically costed or quoted before it enters the shop. There is then a basis. Estimated cost equals x, actual cost equals y. If x minus y does not equal o within reasonable plus and minus limits, questions must be asked and investigation follow.

Cost acccuntancy is still in its infancy. There is a greater field open to practical production engineers in its development than in any other sphere at the present day, and cost control is likely to be the British contribution in the furtherance of industrial productive science. At present not one manufacturer in a hundred has a system that is based upon his own specific requirements or that is not an adaptation of some other that cannot possibly fill the conditions.

HERBERT C. ARMITAGE, M.I.P.E.
(Member of Council.)

Birmingham.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting was held at the Institution of Mechanical Engineers, London, on Friday, January 27th, 1922, Mr. Max R. Lawrence, President, being in the chair.

The minutes of the previous meeting were read and approved.

The President announced that local meetings were to be held as follows :—

Newark Magnus Grammar School, at 7.30 p.m. on Monday, February 13th; and at the

King's Head Hotel, Coventry, on Tuesday, February 14th, at 7.30 p.m.

The President said that he was arranging to attend both meetings, and he hoped that he would be accompanied by Messrs W. L. Fisher and A. T. Davey.

Mr. T. E. Pattinson (Member of Council) then read his paper on "Works Organisation," and in a subsequent discussion a number of the 52 Members and visitors present took part.

It was announced that the next General Meeting would be held on Friday, February 24th, at 7.30 p.m., when Mr. G. W. Eastwood would deliver his paper dealing with the "Intensive Production of Automobile Bodies."

WORKS ORGANISATION.

By Mr. T. E. PATTINSON, M.I.P.E. (Member of Council), Assistant Works Manager, Messrs. Associated Equipment Company, Ltd., Walthamstow.

In presenting this paper the author approaches the subject from a practical viewpoint, dealing mainly with problems which have been encountered in the administration of a large works organisation.

Whilst the observations apply chiefly to mass production and factory methods, the principles involved may be aptly applied to all classes of the industry. A system, of course, to be effective, should be planned to suit the work, and should be sufficiently elastic in nature to permit the addition of any improvements which may be evolved as a result of close study and experience gained.

The perfect organisation of any works, large or small, is the deciding factor in the very existence of the business. This necessary ideal perfection must be initiated from the top—the management. Team work must begin there and be in evidence in every department of the works. Experience teaches that this question of team work is the most vital factor in any organisation.

Having secured the ideal management in an executive body, which is fair, just, and decisive, this is the foundation that may be looked upon as a model for all departments. A special point is made of emphasising the importance of team-work, because the author has never yet, in all his career, been in a factory in which lack of team-work has not told heavily against production. This is the first job a good manager should tackle. He will have plenty of opportunities by holding production meetings, etc., to find out the chiefs who are pulling together and those who are not. Having established this, his immediate duty is obvious.

The staff organisation being brought to the ideal, the *personnel* of the factory should be treated in no less a thorough manner. Departmental chiefs, through the Labour office, should see that they get the best skill available. Apart from the usual records of the candidate's abilities, the departmental chief, who should be a practical man and an expert in his department's branch of trade, can soon satisfy himself of the man's credentials.

Having got the desired brains, team-work, energy, and skill from the management down to the labourer, the programme of output may now be considered. So as to be able to discuss the functions of the principal departments, it will be assumed that a new product is to be manufactured.

The drawing office, in making their design, should be in con

stant touch with the jig and tool department, so that, for example, an extra lug or locating spot for machining may be incorporated in the design—this is important. The drawings released from the drawing office will be distributed, as required, to the order department, planning department, pattern shop, purchasing department, and process of operations department.

Although it is advisable that the process department should form part of the jig and tool drawing office, it should, nevertheless, come under the supervision of an expert rate-fixer. The process department will plan out the sequence of operations in the best possible manner. They should aim at the ideal, even if the available plant does not permit of its attainment. Alternative methods may have to be devised which can be recorded on the process cards. When the time arrives for purchasing new plant this is the department that should be consulted. The rate-fixing staff may also discern that the work is not being done so quickly as might be possible by the installation of a new machine or by a new tool layout, and the safest method in fixing a time limit, if the premium bonus system is in operation, is to fix it as though the conditions were perfect. Any extension of this limit could be provided for by making a suitable allowance.

The question of rate-fixing will be dealt with later, as at this stage it is only desired to urge that the reason for grouping the jig and tool office and the process and rate-fixing department is that the one cannot operate successfully without the other.

The work having been processed and passed by the chief rate-fixer, the jig and tool designer will design the jigs and tools accordingly. By the adoption of a correct procedure at the outset, such incidents will be obviated, as the rate-fixing department, calling for gang-milling two rows at a time and the jig and tool department making provision for one row only. In designing these jigs and tools the designer should make frequent visits to the machine shops. He should have a friendly chat with the operator, who can, no doubt, give him a few useful hints on the peculiarities of his machine, etc.

The jigs and tools designed are now sent to the tool room for manufacture. The rate-fixing department will compute the time settings and schedule the machine allocation. An efficient rate-fixing department should have in their possession records of the capabilities of the machines to which they are allocating the work. They should have recent data of all feeds and speeds obtainable, and not depend upon the machine-tool maker's charts. It has been found in many cases in actual practice that these feeds and speeds are not to be relied upon. This has necessitated, on occasion, a new time setting after the operator has been unjustly under suspicion for dilatoriness.

The question of rate-setting and processing is probably one of the most important in the factory organisation. With the present-

day limitations to the alteration of prices once they have been fixed, the rate-fixing department is compelled to exercise great care, or it may hamper production in such a serious manner that years may elapse before relief is obtained. The author considers that the very existence of a firm is decidedly influenced by this department. The *personnel* of the department requires to be really practical, and not dominated by rule-of-thumb methods. The department should be staffed with men who, if, when the rate is fixed, the limit be disputed, can go into the shops and do the job themselves in the limit they have fixed. Probably this is not possible in all cases, but in practice it will be found the most forcible argument. The author has seen some of these badly fixed limits tolerated for years until a change in jig design has given treble production. He has visited factories and seen work taking four days which he knew could be and was being done by improved methods in four hours elsewhere.

The rate-fixing department should be in constant touch with the estimating and cost office. Any increases in time limits, etc., should be recorded instantly in both the departmental records. It would be deplorable to find the estimating department computing work at a certain figure when that figure was based on months' old records of the rate-setting department, which in the interim had found its time limits were too "tight," and had raised the time without notifying the estimating department.

The jigs and tools being made, there comes into the scheme a very important department—the jig and tool demonstrators. This staff of demonstrators should come under the supervision of the jig and tool department, and should be in close contact with the rate-fixing department. The principal duties of the demonstrators are to try out the jigs and tools for accuracy on the allocated machines, to have the sample work done and passed to view-room limits, and to establish the feeds, speeds, and time limits. This staff is really very essential, as they substantiate in practice what is contemplated theoretically by their brother departments—the jig and tool and rate-fixing.

Before the introduction of this department the author has seen serious delays occur, excuses given that the jigs and tools were useless, time settings had too narrow a margin, etc. It has been his lot, in the early stages, to go out into the various sections and demonstrate personally the efficiency of the tools, establish the fact that the work could be made to pay within the limits set by him, by doing a complete order, and by taking the operator in hand and educating him to the proper use of the tools. Sometimes in disputes it has been necessary to give demonstrations before the shop stewards and the management. These methods never failed to get the desired results.

All jigs and tools should be periodically returned to stores and overhauled, and not only when actual scrap has been made.

Having now surmounted the obstacles generally attendant on the introduction of new jigs and tools, the production stage is reached. The master-key here is the progress and routing department, usually designated the planning department. The utility of this section is frequently brought into question. The query is generally raised by some of the shops which have to be guided in their output by that department. The author has invariably found that the dissatisfaction originates from those who are only partially performing their own particular functions. This desire to do everyone's work generally indicates that the complaining depart-

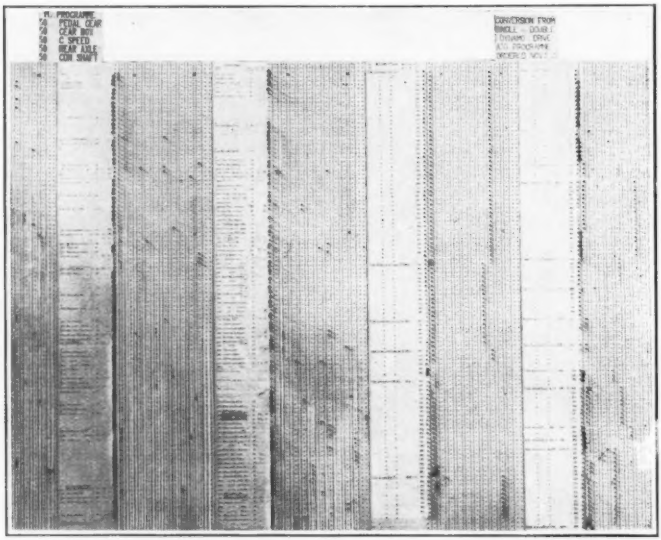


Fig. 1.—One of a series of control boards with peg indicators.

ment itself is in need of overhauling. It may even be in difficulties and attempting to find an outlet for some other department to shoulder its responsibilities.

The principal duties of the planning department are :—

(1) To plan ahead and see that the work is progressed through all departments into stores to scheduled time.

(2) To distribute the work to the correct machines, carefully loading the machines to balance each other in their output.

(3) To issue orders in convenient batches to the shops.

(4) To have all the available data of the progress of the work suitable for ready reference in order to be able to tell instantly the

position of any single item; and to be regarded as the information bureau.

At the works with which the author is associated there has recently been introduced into the planning department a system of peg control boards as shown in fig. 1. The object of these boards is to determine, by the use of different coloured pegs, the precise position every two hours of any given part required by the production programme. Each operation is represented by a rectangle 1in. × ½in., in which there are five holes. A peg in the bottom left-hand corner indicates—job started; bottom right-hand corner, job in view room; top left-hand corner, job waiting for tools; top right-hand corner, job waiting for machine; centre hole—signifies a breakdown. To assist in distinguishing which hole the peg is in, a particular coloured peg is used for each position—purple for job started, green for view room, brown for waiting machine, an orange peg for waiting for tools, and red for breakdown.

In this way one could stand at the end of a row of boards and gain a very fair idea of the condition of the work to which the factory is committed. There is one hole in the material column, and until the material is received a large blue peg is in the board. When the material is issued a small white peg is inserted.

The information is received from the shops every two hours by means of control slips which are printed to correspond with the control board. A cross is placed by the foreman or charge-hand against the statement, and the slip is placed in a box which is cleared at the stated intervals. The more usual card records which are compiled from view-room reports must necessarily be twenty-four hours old, so that the control boards are a distinct advance on the card record system.

It is the duty of every superintendent to visit this control board each morning and ascertain exactly how matters stand. Also every morning a control note advice form, as illustrated by fig. 2, is sent out to each superintendent advising him that certain items are signalled on the board against his department. A copy of this advice is also sent to the works manager's office, who, if the situation warrants, will require an explanation.

The above procedure certainly creates the necessary hustle to get this daily record off the board. A similar system is also applied to machine commitments. This board has weekly dated columns. A coloured peg will denote exactly the week and month to which a particular machine is committed.

For immediate visual inspection this system is excellent and shows the management exactly the departments which are falling down. At the same time, the necessary driving pressure is maintained in the shops by the progress chasers.

The progress and routing department, when properly organised, should be regarded and consulted as the information bureau, and

the perfect co-operation of all departments is essential for its successful working. This department must ever be alert for possible drains on its scheduled output by the making of scrap, etc., and take immediate steps to make up any deficiencies.

In coming to the machine shops, it will be assumed that the

Sheet Nº 1
Nº of sheets 1

CONTROL BOARD

To Mr. --

Date 28th December, 1921.

Dept. JIG & TOOL DRAWING OFFICE.

Please note the following parts were signalled against you at 8.30 this morning on the Control Board waiting for JIGS & TOOLS.

Part Nº	Description	Op. Nº	Date First Advised	Remarks
C.21701	Clutch Stop Arm	2	17.12.21	Dept. 21. A34/1 Waiting Jig.
G.13804	Con. Rod Sup. Bkt.	1	10.12.21	Dept. 64. A34/1 Waiting tools.
J.10801	Clutch Spider.	2	22.12.21	Dept. 21. A.34/2 Waiting Jig.
K.20301	Sldg. Card Jaw.	5	21.12.21	Dept. 20. A.30/2 Waiting Drifts.
M.10701	Steering Fork.	3	9.12.21	Dept. 21. A34/1 Wtg. Milling Jig.

Operator's Signature

COPY TO WORKS MANAGER'S OFFICE

Fig. 2.—Control board advice sheet.

machines are in reasonable condition and that all the jigs and tools for production have been demonstrated to be efficient, and that the time limits are correct. The chief duty of the machine shop superintendent is to concentrate on quantity and quality. He should see that he secures the best skill available; it is also

his responsibility to see that he has the best foremen under his control. The author is of opinion that at times it is an excellent plan to obtain these men from the departments in which they have worked, as they are in such cases fully alive to the peculiarities of the machines and also the special units for which they will be responsible. The ideal machine shop superintendent should be an expert machine shop man, in addition to being a good organiser. He should make it his duty to keep in close touch with the men; he should have a friendly chat with them from time to time, and really be their champion when in distress. He should be the man, when his understudies fail, to put matters right, either technically or socially. The superintendent who possesses these essential qualities will obtain the best results. The human element in system, as well as in organisation, is without doubt an essential factor. It is considered in some quarters that, so long as a man holding an executive position is a good organiser and not a practical man in his particular work, he is good enough. That is not the view of the author; rather he considers it tantamount to inflicting grave injustice on the men supervised. One has heard of a linen draper holding such a position, but one would not go to a butcher for a new suit. No, for the best results can only be attained by selecting men for the executive positions in the works who can give the persons they supervise the necessary helping hand at all times.

The ideal machine shop and whose product is repetition work will have the machines carefully grouped so that the work may pass from one operator to another without transport. The machines should be subject to frequent inspection by an inspector specially delegated for the duty, and his timely advice to the millwright's department should effect a considerable saving in the end.

It is difficult, without consulting the foremen, when walking through the machine shops, to learn why certain machines are idle. The reason for this position would be recorded by the progress and routing department on the control boards, but a coloured label tied on the machines, such as red for machine breakdown, etc., would be an instructive guide to the manager as to the exact position. When one considers the great amount lost through idle machines, it is of the utmost importance that the management should be fully conversant with the true state of affairs. If there is work to be done and the machine is in running order, yet remains idle for any length of time, it should be looked upon as waste of the most serious nature.

In dealing with the scrap from the machine shop it is not altogether satisfactory to be faced with an average amount per week. The best plan is to deposit the scrap each week in a separate room. Every Monday morning a committee comprising a representative of the management, the machine shop superintendent,

the view-room superintendent, and the jig and tool superintendent, should investigate the cause of the scrap and take immediate steps to prevent a repetition. Should it be decided in committee that the jigs and tools are not right, these must be corrected at once. In some cases it is also advisable to have the operator before the committee, for he may have some reasonable excuse which may enlighten them. The object of the committee should be (1) to investigate and truly to record the direct cause, and to allocate the responsibility to the correct department; (2) to take immediate steps to eradicate the possibility of recurrence; (3) to reclaim scrap which can by reasonable methods and cost be saved, without affecting the standard dimensions and quality of the work.

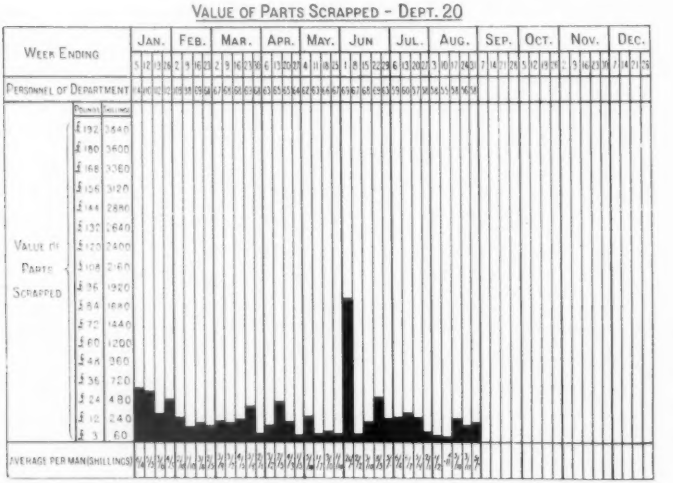


Fig. 3.—Example of chart showing scrap, for exhibit in shop.

The question of the individual value of any employee will now be discussed. It behoves the management to keep the best, and in such times of trade depression as the present it requires very careful consideration before any man is discharged. The firm with which the author is connected introduced, some years ago, a scheme of individual efficiency, the idea being that the workman is given every credit for all the good points he makes by good time-keeping, bonus earned, etc. Each workman is placed at 100 per cent. efficiency. For lost time, scrap, debts, tool breakages, etc., he loses a given number of points. If the above scheme is carried out with discretion and used as a guide, it is believed that there is no fairer scheme. For example, Brown works next

to Jones. Brown says: "I don't want to miss any time," and arrives punctually at work. Jones says: "I would like to get in to time, but I can't." Result, Jones is losing points on time. Now when Jones gets there it will be supposed that he pushes forward with his work and turns out more work than Brown, but at the same time Jones has scrapped some of his work, while Brown, slightly behind Jones's time, has no scrap. The amount

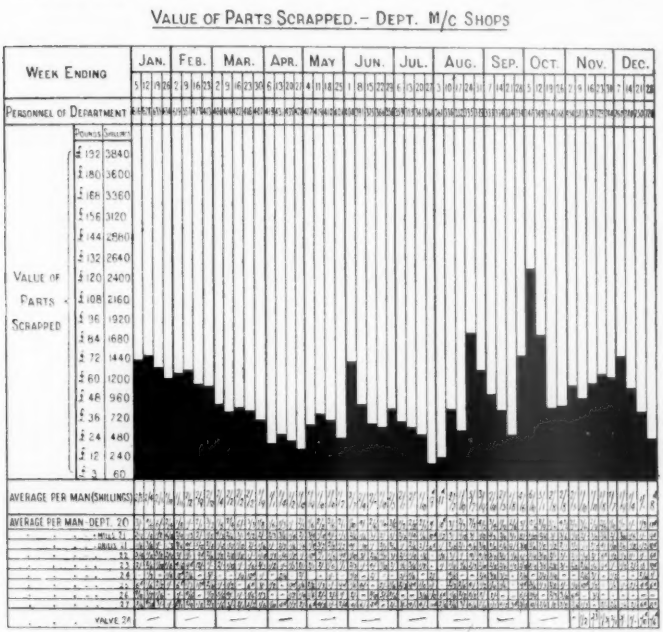


Fig. 4.—Master chart showing total amount of scrap made (machine shops).

of bonus earned, therefore, in Brown's case will be more than Jones, after Jones's deduction for scrap. Brown, therefore, has a higher efficiency by good time-keeping, bonus earned, and the least scrap. Now the time for discharging comes along. Jones, the lower efficiency man, goes. Jones may be a personal friend of the foreman, but of no avail. It is often the case that one point may divide the two men under review for discharge. This scheme certainly does place the onus on the men themselves, and removes the possibility of victimisation from supervisors.

It has been found advisable, in order that the men may be

informed of the scrap in their departments, to keep in a case a scrap chart, which is made up weekly and is exhibited near the time clocking racks. This gives the total amount of scrap and the average per man, and such a chart is illustrated in fig. 3. A master chart of all departments is also made for the manager's office, a typical chart being shown in fig. 4.

A monthly scrap chart is also sent to all foremen, which shows the amount of scrap and loss in production hours in their departments, an example of such a chart being illustrated in fig. 5. The position is discussed by the management with the respective superintendents.

It has often been found, on investigating the cause of scrap, that

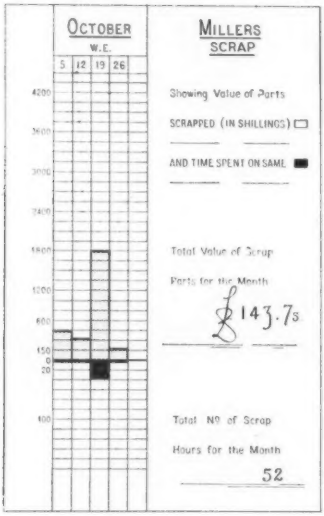


Fig. 5.—Monthly scrap chart.

the operator was not to blame, owing to the fact that the foreman had not given him precise instructions, or had given him an incorrect drawing of a part which was very similar to the correct one. Many instances similar to those cited have occurred, due simply to bad supervision. A chart has been specially provided for such cases, and has been designated, "Loss in scrap and productive hours attributable to defective supervision." This is illustrated in fig. 6. The chart is hung in the manager's office, and is recorded monthly. All cases coming under the heading of the chart are decided by the management. A few days before this record is made up the superintendents concerned are notified that

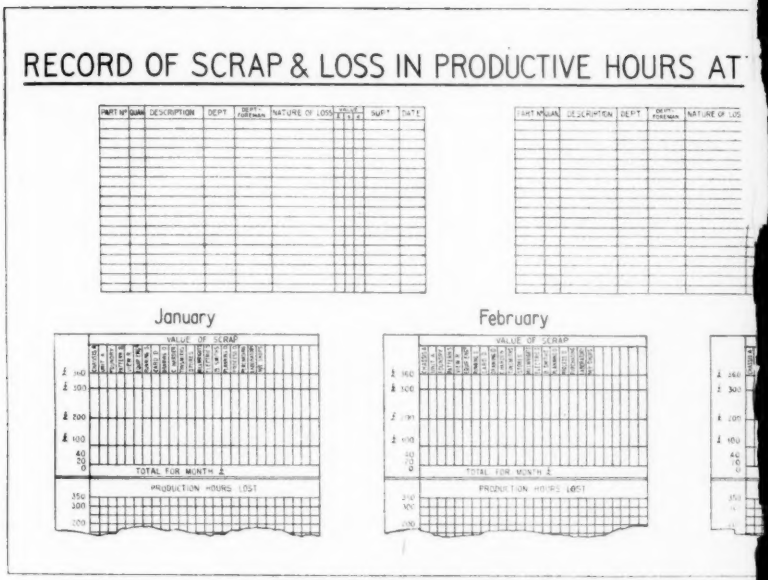
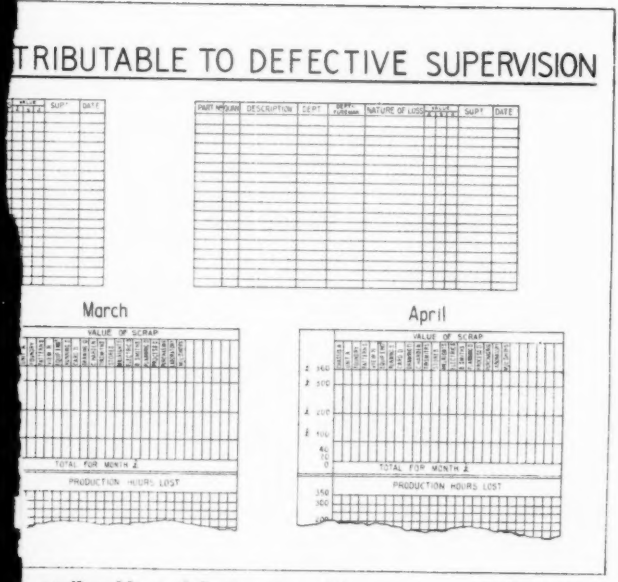


Fig. 6.—Chart showing scrap and loss in productive hour



s attributable to defective supervision.

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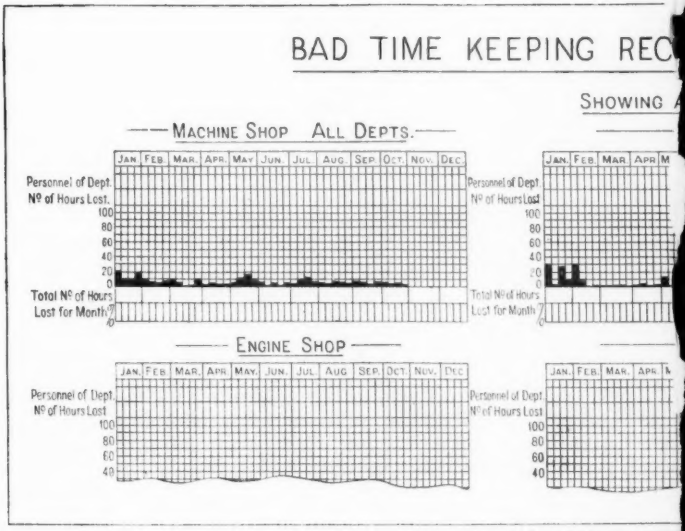
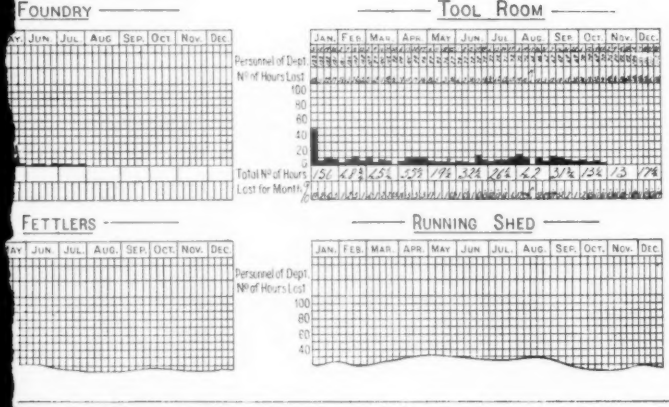


Fig. 7.—Example of chart showi

ORD OF FACTORY. 1921.

AVERAGE PER MAN



ng departmental bad time keeping.

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certain charges due to defective supervision are being charged up against them for that month. In the interim they have the opportunity of investigating, and, if necessary, disputing the charge. It is found that this record really does good, and makes the departmental chiefs more alive to their responsibilities. As an illustration, a case in point will be given. The chart is made to record one year. It will be assumed that an inefficient foreman is in charge of a certain section. This section records very high scrap on the factory charts. The particular foreman repeatedly has a great amount of scrap which could have been avoided had his supervision been good. The time arrives when it is decided to discharge this foreman. He may appeal to his superintendent, and possibly state that he is being unfairly treated. The superintendent states that his decision must stand, and the foreman then appeals to the works manager. The works manager will hear the case of the foreman and will consult the supervision chart. He finds the records very bad against the foreman, and will perhaps say, "On January 31st you cost the company £140 scrap and 300 production hours were lost by your instructing the operator to 'carry on,' although the first sample to the view-room had been rejected. In February you cost us so much," and so on. The foreman will then realise the position. These records are solely for the management, and are not allowed to be a shop topic.

For the management's review, a bad time-keeping record chart is drawn up as illustrated in fig. 7. This chart is designed to record for one year, and shows every department in the factory. The statistics are made up weekly, and show the average time lost per man in minutes. It records the exact number of men in each department, each week, and gives the total number of hours lost in the department for that period, and the percentage. This record is very useful, as it gives the management the immediate visual position of all departments, and for any week in the year gives the exact *personnel* of any department.

Before disposing of the machine shops, the author would add that, in his opinion, insufficient attention is paid in this country to the very necessary grouping of machines to provide for their respective units. It is really amazing to note how in some works a particular part travels all over the factory before completion. When one considers the amount of transport, damage in transit, loss in time, etc., this is a very important question, and careful planning will result in a very great saving.

In viewing work, the author is a strong advocate of walking inspectors; that is, on light work that does not require lining-out slabs. He has worked under this system in the States, and must say it saves a great amount of time and scrap by the timely intervention at the machine on the part of the inspector.

With regard to the general output of the machine shops, it is

considered a wise plan to be a few weeks ahead of the allotted time, in order to provide for the contingency of defective material, etc. The machine shops are the heart of the whole works; and upon them depends, to a great extent, the output, as all other assembly departments, etc., arrange their work accordingly. Any failure on the part of the machine shops would disorganise the whole programme.

In approaching the subject of unit assembling shops, it is felt that one must get down more to time and motion study. It is very exasperating to walk into the shops to find a man who has been on the same class of work for months hunting all round for a spanner; it is equally annoying to see him filing certain parts that

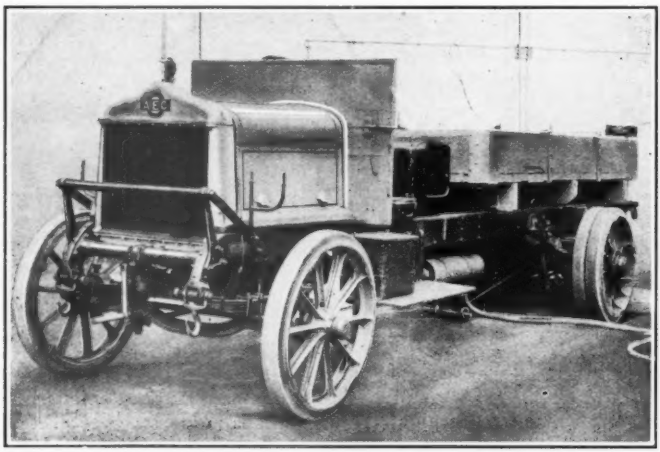


Fig. 8.—Chassis in position for dynamometer test.

should have been machined correctly. When the factory is on full production, an even flow of output from the unit assembling shop is very essential, in order that it may work in unison with the travelling platform used for assembling. The success of the whole scheme lies in ample stocks of units in the assembly bays.

The following is the author's vision of what is considered to be the ideal: In building the units much time could be saved by travelling cradles designed to house components. Alongside the track are built special store bins. The unit will start at one end of the track and travel, after each operation, to the next position, fitters taking their requisite parts from their store bins until the unit finally reaches the end of the track, complete. At the end of the track will be an aerial cable having communication with the

assembling departments. The complete unit, before leaving the assembly cradle, will be hooked to this aerial cable. The unit will then speed on to its destination by gravity to the unit store bays. The unit bays are built alongside the assembling travelling platform, and are positioned according to their order of assembly. Each unit stores should have its own separate communication cable, connecting it direct to the previous assembling departments. The unit will remain suspended by the same hook as when it started from the unit assembly shop, and will not be released until finally dropped into position, no human effort or lifting power having been necessary in transport or for the placing of the unit in position. This aerial transport system, it is felt, could be utilised to great advantage in effecting communication to all departments up

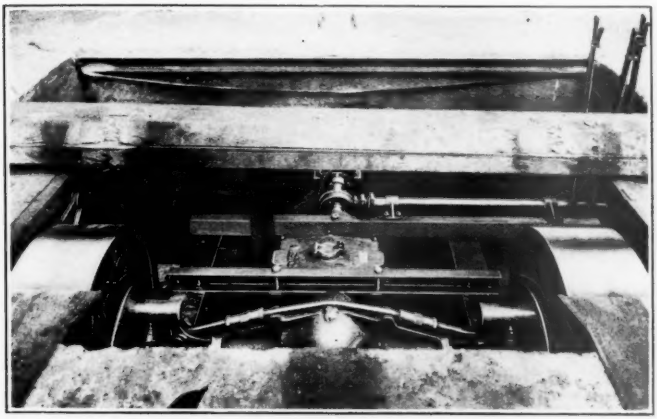


Fig. 9.—The dynamometer test equipment.

to the finished stores. It would obviate much damage in transit, and it would save labour and costly runabout trucks.

As a matter of interest, it might be stated that the company the author serves have recently installed a system of testing vehicles on a dynamometer, instead of sending them out on the road. Some views are given in figs. 8, 9, and 10 of a commercial vehicle under test, and of the testing apparatus. The results are highly satisfactory, and have been the means of saving a great amount of time and labour. The importance of this method of testing will be realised. Suppose, for example, forty motor vehicles are being produced per week. Prior to the use of the dynamometer, this would mean a constant fleet of vehicles being tested on the highways. When one considers the possibility of dilatory tactics by the testers when away from factory control, the attendant risk of accidents,

claims for damages, extra testers, etc., this is indeed a useful innovation.

Even in the best regulated factories there are always troubles relative to production that require investigating and settling without delay. To provide for this, there has been established a "trouble engineer," or "trouble investigator." This investigator is under the management's supervision, and he has proved to be a very valuable and useful man. Whenever difficulties arise in any department this man is immediately notified; in fact, he does not need to look for trouble; it is thrown at him. He is kept continually busy. For example, engine assembly shop report "Back

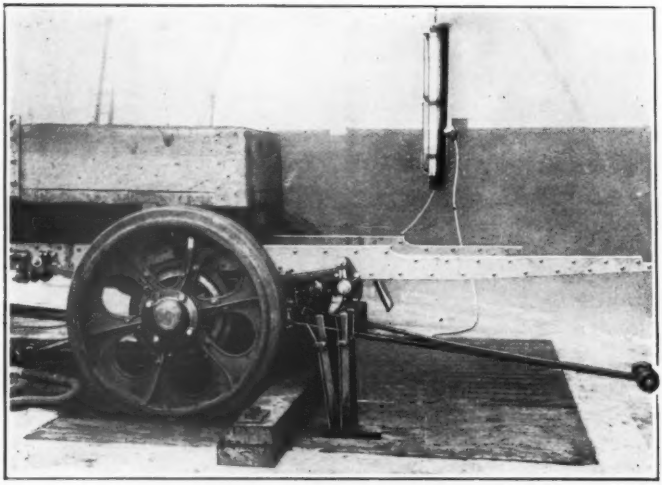


Fig. 10.—Chassis under test.

axle casing—insufficient clearance in sump—worm wheel fouling." This man will then take up with the drawing office, then the pattern shop, having the pattern altered, and advising all concerned of the alteration. He is a thoroughly practical man, offers suggestions for improvements, has experiments carried out, and is a link connecting all departments. Every complaint he receives is recorded, the time and date when made, and how settled by him. His duty is to see that these complaints are properly and immediately adjusted, and that all alterations are noted on the drawings to prevent any recurrence.

Another very useful man the company have appointed is the "salvage man." This man knows every corner of the factory.

His duties are to collect and sort all the scrap or anything lying about the factory that can be turned into cash. The importance of a man of this description, who knows the factory, will be appreciated by the recounting of an actual incident that occurred during the war. The author was assigned the position at that time, and was responsible for all jigs and tool steel, etc. The shortage of high-speed steel and the high price obtaining at that time will be remembered. In one shop—the blacksmith's—an accumulation of tools was discovered which, to all intents and purposes, was non-existent. No one except the blacksmith knew they were there. They were hidden away in a corner and had been there for years. The value of this find was £1,240, and this at a time of an acute shortage of high-speed steel. The salvage man does all this sort of work now, but the case in question will illustrate what a great amount of wealth may be lying dormant in a factory. It is the salvage man's duty to collect and sort this superfluous material. The purchasing agent then sells it in the right markets. One might say, "Well, there is something lacking in a works administration to allow this sort of thing." It must be borne in mind that this was the accumulation of years, and it is only what appears to happen inevitably in the best conducted factories.

There is really no excuse for a factory organised on the lines laid down and with the necessary plant available failing to produce to schedule. It simply means that someone is not doing his job if the output be not maintained. The reasons can easily be discovered, as all departments are working to schedule, and the planning and routing department can readily learn the sections not giving the requisite output per week.

In dealing with the *personnel* of the factory a few observations will be made as to the relationship between employers and employees. When the author was working in the shops some years ago every move of the employer was watched with more or less suspicion—and it is the same to-day. Why? In some cases the employers were to blame. Their factory had been equipped with staff who knew little or nothing about their jobs. For the sake of illustration it will be assumed that against such an organisation another factory commences operations in the same line of manufacture but with a really practical and ideally efficient staff. Competition arises, and the perfectly organised factory forges ahead with hard and fast rules and time limits rigidly and scientifically fixed. The badly organised factory now feels the pinch of competition and tries all sorts of methods to shake off the stranglehold. It resorts to cutting rates, etc., in order to reduce its costs, and at the same time automatically sows the seeds of distrust amongst its workpeople. It might be remarked, "Why, because the management has had to cheapen production, should the men kick?" The answer is, it should never have been necessary if the people at the top had known their jobs.

This is mentioned because the importance is felt of such a body as the Institution of Production Engineers for the ventilation of these matters. From the men's point of view their (the men's) organisations have their extremists, it is true. When sitting at the Employers' Federation meetings and listening to the discussions relative to the welfare of the workers the author has recollected the days when he was in the shops, and has thought that if those men were only there to listen to the careful thought expressed in the discussion for their welfare by that representative body of employers, the malcontents would "bury the hatchet." It appeared to be so different from what was, and is, pictured to-day in the shops.

It must be remembered that a mechanic has to travel and at times finds employment in all kinds of factories. Before he reaches the efficient factory he may have been in some place which has, through its bad organisation, imbued him with a spirit of distrust. He may be slow to realise that the efficient factory is not "in the same boat," but after realisation does come he will doubtless be numbered amongst its oldest and most reliable employees.

The author is acquainted with one firm which have factories in the States as well as in England. They have a weekly bulletin giving the comparative output between the English and American factories working under the same limits and conditions. The English output is much below the American. Why? Having worked in the American workshops, the greater output cannot be attributed to any better conditions prevailing in the American shops. This is a question better left for the workpeople of this country to answer.

One fact is patent—there is much spade work yet to be done in this country to improve the relationship between employers and employees. By all means let us extend our welfare work, carry on with our sports, but not to the extreme. But we must put our own houses in order, to commence with, as the foundation. The workpeople are blamed for lack of unity. The author blames the employers equally as much. If it be a federated firm, let that concern carry out its responsibilities according to the guidance of the Federation. The knot of the bond of unity has still to be tied by the employers themselves. Encircle in this bond the welfare of the workers; impress on them by just and decisive actions that they are not part of the tools they operate. Make them feel that their endeavours are appreciated by giving them every encouragement. Let them regard the firm's success as their success; deal decisively with the malcontents that are found at times to creep in with newly engaged hands, and let such dealings be regarded by the workpeople as an act of protection for themselves as well as for the firm. Don't create unfair competition in the labour market by offering your workpeople better and higher rates than your neighbours. The author has had bitter personal experience of this

in building up the *personnel* of a new factory. By such methods is created a situation which can only end in disaster.

Fig. 11.—Automatic telephone switchboard.

In some of the previous remarks the problem of the ideal in the organisation of the factory has been outlined. Perhaps, therefore,

before closing these notes it will be interesting to learn what progress has been made on the way to the ideal in the factory at Walthamstow. A number of illustrations of proved labour-saving devices will therefore be given in exemplification of what has been accomplished.

Automatic Telephone Installation.—This installation, which is illustrated by fig. 11, is a great time-saver. A call can be made automatically in five seconds, and thirteen conversations can be carried on at the same time. The board is arranged at present for 130 lines, 120 of which are now in use, but it can be extended if

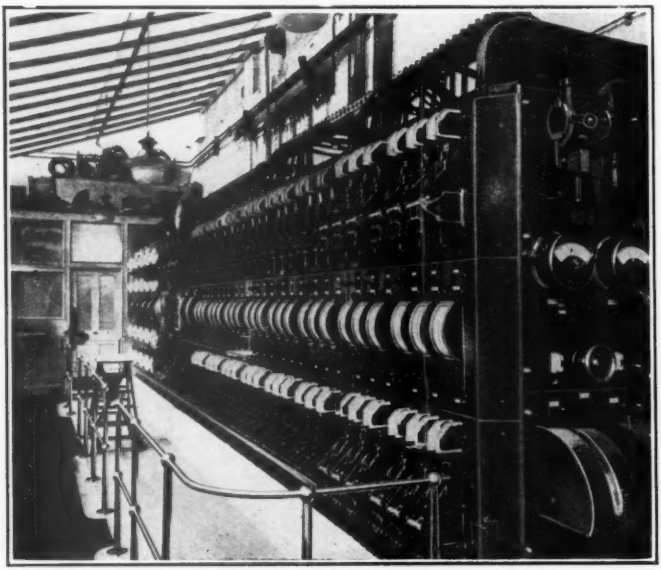


Fig. 12.—Main works switchboard.

necessary to 200 lines. In case of fuses blowing out or any part failing, alarm signals are brought automatically into operation and indicators locate exactly where the fault is. Every departmental telephone instrument is given a number. To engage this number a small perforated disc is rotated, the distance of rotation being controlled by the number required. This is a great improvement over the previous method of waiting for an operator to obtain one's call.

Electrical Main Switchboard.—This is shown in fig. 12. The importance of this switchboard will be realised when it is

stated that there are 215 motors running at one time in different parts of the factory. These are mostly of 20 h.p., all standard Veritas-Aston type. The motors are fixed on a gantry above the machines, which enables the motors to be inspected and changed in a very short time. The overhead construction is to be seen in fig. 13. Should any of these motors develop trouble, it is instantly recorded on the main switchboard. There is also a lighting section on this switchboard which controls the whole lighting of the factory.

Testing Petrol Engines.—Engines are tested on British Thomson-Houston dynamometer stands, the engines being run for

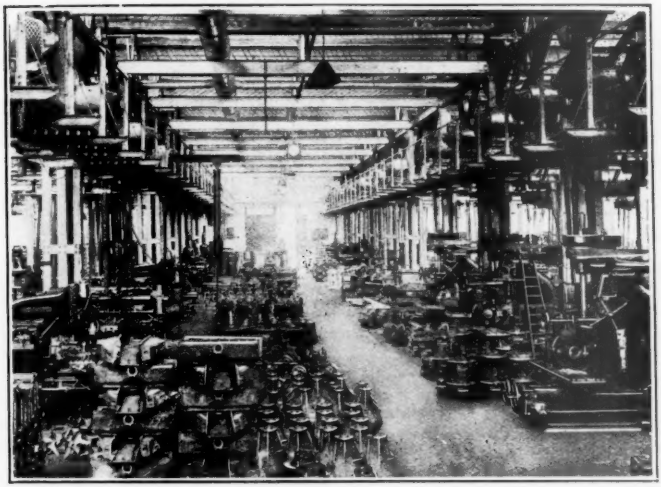


Fig. 13.—Overhead gantries for motors in machine shops.

a period at certain speeds by the electric motor. The electric power is then switched off and the engine is given certain tests under its own power. During these tests the dynamometer is engaged, this time being driven by the petrol engine and generating current back to the main switchboard through a B.T.H. balancer. In fig. 14 is illustrated the engine test dynamometer.

Paint Spraying Apparatus (not illustrated).—This is operated at a pressure of about 20lb. The time for paint spraying one chassis by two men is 18 minutes. By the old method of painting, four men took one day.

Auto Call.—This system is worked with 230-volt single-stroke bells which are fitted in various parts of the factory. They are

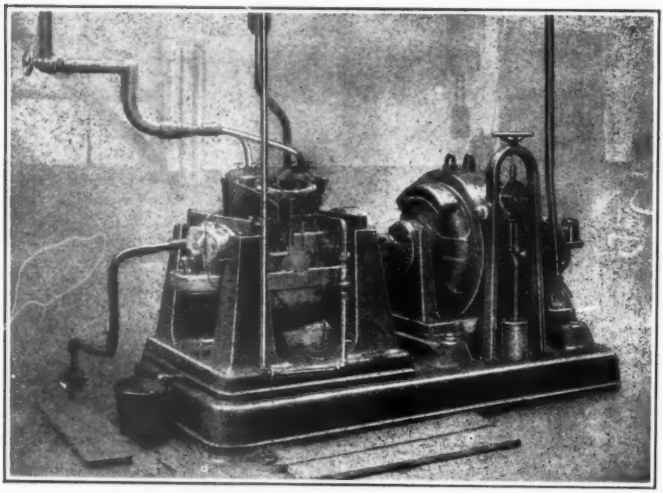


Fig. 14.—Engine test dynamometer.

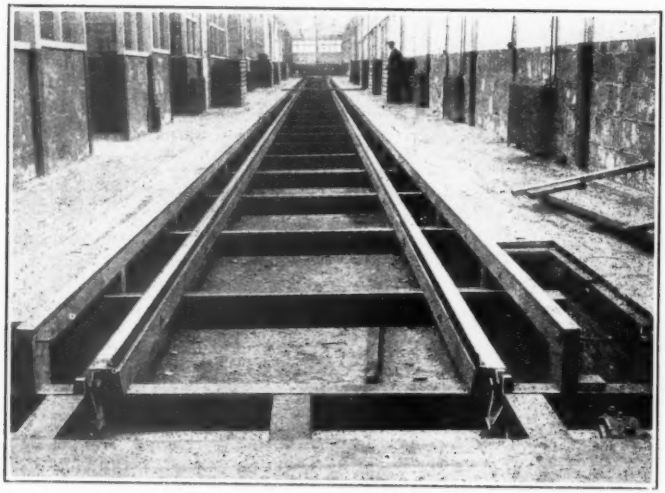


Fig. 15.—Construction of the travelling platform.

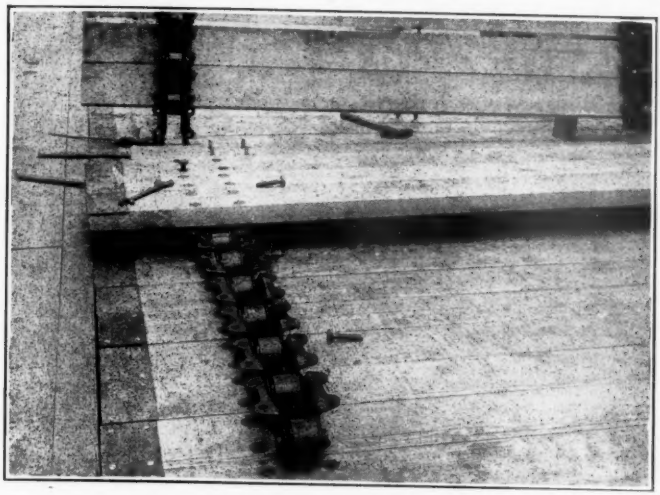


Fig. 16.—Arrangement of assembly track links.

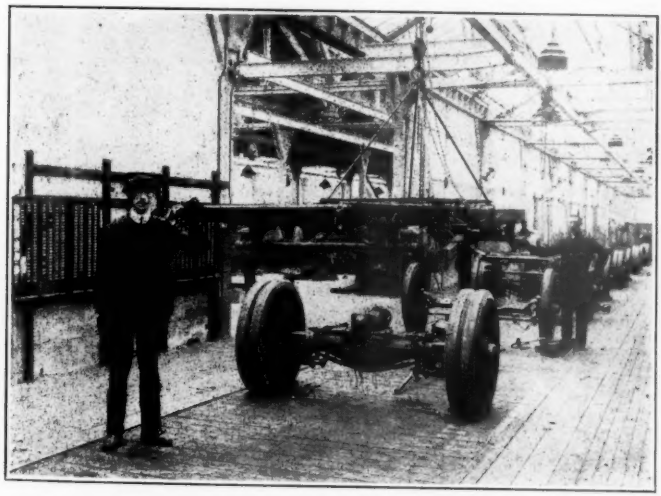


Fig. 17.—First operation on travelling track.

controlled from a central operating station, which in this case is the telephone room. If any person who is on the list of auto-call numbers is wanted, the telephone operator plugs the number allotted to that person, and the bells indicate this number in all

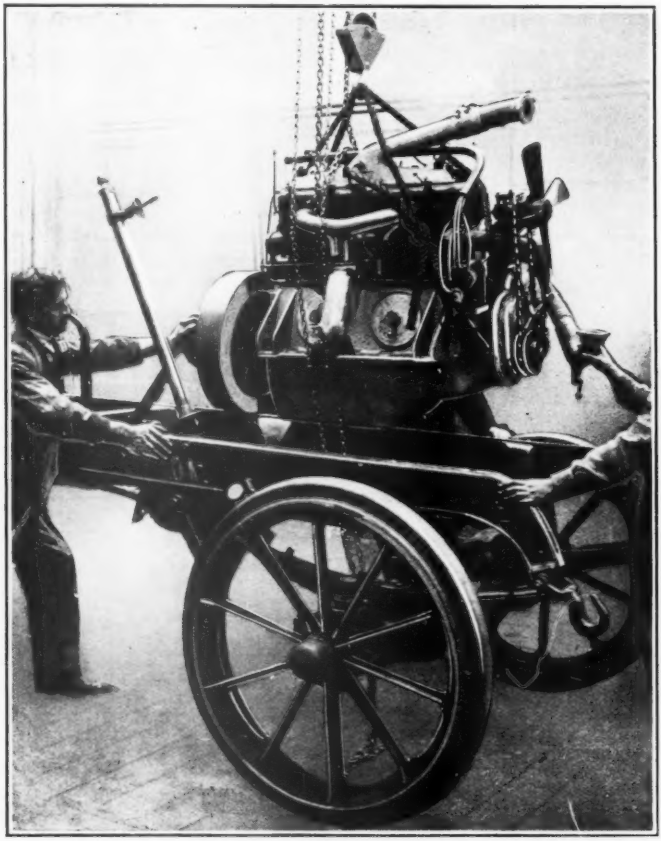


Fig. 18.—Engine assembling operation.

departments until the telephone operator receives an answer on the telephone from the person being called. The control board for this call system in use at this factory is a thirty-line board. It is portable and the weight is about 37lb.

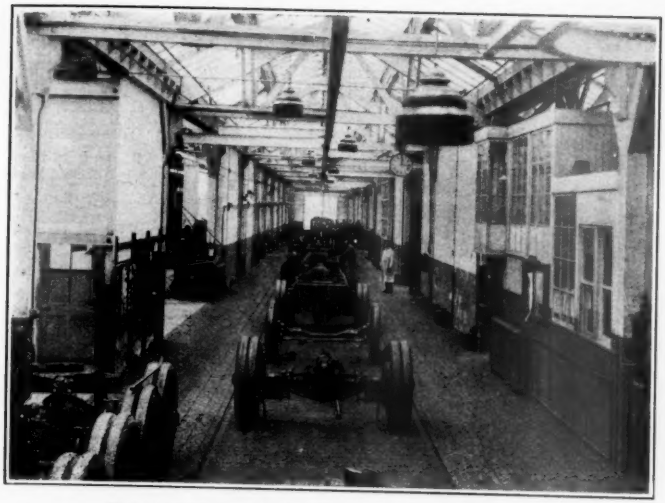


Fig. 19.—General view of the assembling track.

Fig. 20.—Progressive engine assembly.

In the earlier portion of these notes reference is made to chassis assembly on the travelling platform. In fig. 15 is to be seen the track on which this platform is built. The method of fixing the boards on to the tractor links is illustrated in fig. 16. The platform is driven by a 5 h.p. variable-speed motor through a worm and spur reducing gear with a reduction of 4,800 to 1.

The first operation on the travelling platform is illustrated in fig. 17. This shows a pair of assembled axles and wheels already tyred placed the required distance apart on the moving platform, with the chassis frame being lowered into position. In fig. 18 is shown the engine being lowered into position. An illustration is given in fig. 19 of a platform full of chassis, each chassis being in its relative progressive stage to the complete chassis at the end.

The complete assembly of a chassis takes about $3\frac{1}{2}$ hours. The placing and fixing of the several components average 25-minute stages. The speed of travel of the platform is 11 to 12 inches per minute.

In fig. 20 is shown the progressive assembly of the engine on a rail track.

The author begs to be excused any omission to mention all departments of the works organisation such as the costing section, etc. These subjects, it is felt, have already been admirably dealt with recently, and there is no desire to take up time on matters that have formed the subjects of recent discussion.

Don't over-systematise. Make every new innovation prove itself as a paying proposition. Don't have a works resembling a paper factory, or have such cases as a fourpenny bolt costing a shilling by innumerable paper records. Don't have No. 3 office communicating with No. 4 with unnecessary typewritten epistles. If factory rules are exhibited on the walls, keep to them or tear the notices down. Make sure, as outlined in the opening remarks, that the works team is up to concert pitch. At any signs of breaking away pull up the reins and decisively remove the restive element.

THE DISCUSSION.

THE PRESIDENT, in opening the discussion, expressed the thanks of the meeting to the author.

He pointed out that the Associated Equipment Co. were making 3- and 4-ton chassis and the London buses, and they would all agree that the system described was highly suitable to that class of factory. No doubt the sub-division that had been made of the various functions of the several departments had been largely influenced by the *personnel* at the time in charge of these departments, and which was available for taking on the new functions in a new department when it was formed. He himself had covered the ground in similar factories rather differently, and it had been his practice in one factory to place the planning department under the tool room. The tool room superintendent had under his supervision the jig and tool design office, as well as the processing of the parts and the construction of the jigs and tools. Probably if the *personnel* had been of a different character some better scheme might have been evolved. Therefore he felt that, whilst they must all be in general admiration of what had been developed so successfully by the author, still they must pay him the compliment of criticising. He was in complete agreement with the author when he called attention to the fact that the executive and works officials should understand their job. In the beginning—and every works had a beginning—the chief had many functions to fulfil. He had to select and design a product that was wanted, and had to make it at the right place. He had to possess the necessary financial resources, to obtain the right plant, and to arrange the selling side of the business. At first, when the works were small, he probably managed them himself and also purchased the raw material. As the work developed he had to call in extra help, and it was in choosing the right people to help that the real test lay. In order to be successful the right men must be selected. If the guiding force could not do this properly and see that the men developed with their jobs, then it came about that the methods employed were unsuitable, and it could be said that the men in the top positions were supervisors who did not know their jobs because they had not kept abreast of the times. It was by joining such bodies as the Institution of Production Engineers, attending the meetings, and discussing production problems, that men could most readily increase their knowledge, keep up to date, and so fit themselves for higher positions.

With regard to some of the descriptions of equipment outlined in the paper, the dynamometer illustrated had very much interested him. He, himself, had put in a similar dynamometer when he was with Messrs. Lanchester in 1901, and he believed the actual machine was still working. The pulleys that the car ran upon were 7ft. in diameter, so that they had a circumference of exactly 22ft., which was $\frac{1}{240}$ of a mile, so that 240 revolutions made a mile of travel.

It was discovered that the chassis had to be very securely anchored, otherwise it oscillated in a most curious manner. Another thing he had tried at Messrs. Lanchester—it was not successful—was to put into the periphery of these pulleys the actual weight of the car, thinking that he could teach people to change speed on this drum. It was true that the inertia of the revolving drum was the same as the car travelling on the road, but when the brake was put on it did not quite reproduce the effect of mounting a gradient, and, morever, it was necessary to have the visual effect of movement to time the changing gear correctly.

The conveying system which had been described in the paper was very interesting, but that needed a very large and concentrated output to justify the expenditure. He had found that a great deal could be done to save transport of pieces in the works by suitable grouping of machines and assembly in one department. By completely machining and assembling such units as carburetters, cylinders, etc., in a department under one foreman and providing him with sufficient machinery and castings much benefit was derived, and the system has since developed rapidly, although the geography of the works made it difficult to arrange.

Mr. J. D. Scaife sent to the meeting a note of apology for his inability to attend, and communicated the following observations.

The author is to be congratulated on his initial contribution to the Proceedings of the Institution. The subscriber can speak with first-hand knowledge of the magnificent works and organisation described because of his connection for some time with a neighbouring firm. As it stands the paper can be taken as a good general working basis for students of the science of production. The paragraphs on team work cannot be too well assimilated, as, without the spirit of comradeship among the supervising staff, the most perfect equipment will lose considerably in efficiency, and a sufficient lack of such a spirit will certainly bring any organisation to the ground.

The author's statement is fully endorsed that a system to be effective should be planned to suit the works. Attempts to transplant a system *en bloc* usually ends in disaster. Even in two works handling the same class of product the same system will rarely work well without suitable modifications to meet local conditions, such as the class of operating and supervising labour obtainable, etc.

As a working basis for discussion it might have been an advantage to have had a chart showing the relationship of the various members of the staff to each other, as it is not quite clear how the various departmental heads are connected, and not all the principal officials necessary in a large organisation are mentioned. The chief difficulty in the way of a smooth and efficient organisation is usually, according to the writer's observation, a lack of definition as to where responsibility begins and ends. Any doubt on this point between two officials of approximately equal status is sure to prevent the essential linking up of forces. In a recent paper presented to this Institution such a descriptive chart was projected on the screen. This chart showed the relationship between the various members of the staff of the firm with which the writer is connected, and was reproduced in *Engineering Production* on October 6th, 1921. It would be interesting to have the author's ideal organisation in a similar form. In that case all the various important officials could be connected, together with a brief description of their duties. A rather serious

omission is that of the position of the metallurgist, which in a large engineering works is now a very important one.

There are one or two points which the writer would like to discuss; the first is in the opening paragraphs where the author advises the jig and tool drawing office to come under the supervision of an expert rate-fixer. The subscriber suggests that unless the rate-fixer had developed into something resembling a production engineer or works superintendent (who had actual rate-fixers to do the detail work), the average chief draughtsman would not relish his position. If the rate-fixer occupy the status outlined above, there is agreement on the point. With the suggestion that the jig and tool demonstrators should come under the jig and tool department the writer respectfully disagrees, and would advance the opinion that they come under the rate-fixer if they are to exist at all (the writer has never found them necessary or advisable), for the reason that if the jig or tool has been made to drawing and passed the tool-room inspection, it is the direct business of the rate-fixer to demonstrate its utility, and no responsibility can be attached to the tool-room for its behaviour. Further, the tool-room and operating labour are usually of different grades which it is not desirable to mix. It is the writer's custom to treat the tool-room exactly as an outside contractor, and to obtain competitive prices from time to time in order to check costs—placing orders, of course, with outside firms if they are in a position to manufacture more economically.

The question of the relationship of the designing department to the manufacturing departments, together with the process and final examination of the product, is one which receives a variety of answers in different shops, and these points might be embodied in such a chart as the writer has suggested.

The pegged control board described has some new and interesting features. It is not quite clear to the writer, however, how far such a board could be modified to suit all classes of product.

Material is, for the most part, received in a certain quantity per week, and is carried through the shops in a given quantity per week, with the result that some components might be in four or five stages of progress simultaneously. It would be interesting to learn whether the board could be made to suit these conditions, and how.

Mr. Bell said that it was exceedingly difficult to criticise a paper which contained so much solid matter as this one. He was pleased to see the author regarded as of such importance the question of team work. Unless there was team work in a factory there was nothing to hope for but the results the author had mentioned as regards disorganisation and failure to get out the work in the time and in the condition in which it ought to be produced. The question of rate fixing and processing, as the author said, was probably one of the most important in factory organisation, although he must say that the impression created in his own mind was that the system in use at Walthamstow was very complex. Nevertheless, the author had undoubtedly got simplicity in mind, as he said at the end of the paper "Do not over-systematise." It was rather difficult to realise that they were not over-systematising at Walthamstow, in view of the exceedingly complex charts and methods which were in use there. On the other hand, the factory was so enormous and the quantity of work passing through was so large that it was

quite possible that the impression of over-systematising conveyed by the paper was not correct. He was very interested in the point raised with regard to jig and tool demonstrators. The jig, after being made and checked, might be quite correct, but he had always considered that it was worth while to show the operator exactly how that jig should be used. Very often slight modifications might be devised which were only discovered during the actual operation of the appliance, and to leave the workman merely to find out things as best he could was not fair either to the workman or to the factory. The question of giving demonstrations before shop stewards and the management he also considered to be exceedingly valuable. Demonstrations of that description very often removed misunderstandings which otherwise would inevitably arise. The various charts, particularly with regard to scrap, were exceedingly interesting, but he was sorry for the works manager or the assistant works manager—as it was in this case—if he had to absorb all those charts; he was going to be fully occupied.

With regard to the grouping of machines, that was dependent in every case on the product. In some cases it might be possible to group the whole of the operations in one small corner, and turn out the finished part from that particular corner. In another case the part might have to go through quite a long series of shops, and the problem of grouping could only be settled in each shop and in relation to each part. The question of available expenditure arose in this connection, and, in fact, it was a matter which was wrapped up with the whole of works management. Nevertheless, it was a point which required, and deserved, an enormous amount of thought. He agreed with the author as to the importance of walking inspectors and the desirability of faults being spotted at the machines at the time they occurred, or as soon after as possible, otherwise they might get huge quantities of scrap sent through to the view room, and the whole of the production disorganised. Unit-assembling shops and time and motion study were matters which had not received the attention they deserved in England. Certainly, in the shops in which he had been, time and motion study was a matter which the English workman was still very sore about. He did not understand it, and a good deal of education still remained to be carried out on these lines, but it must be done openly. There must be no suspicion, and no surreptitious wearing of a stop-watch by the inspector. It must be shown openly, otherwise there was suspicion of unfair dealing which might not tend towards the best results for production.

As regards moving tracks and tramways, that again had to be dealt with according to individual practice and the particular product and the amount of space and cash available for that system regulated the development which was possible. In one case in which he had control he had found that moving stores were really better for the particular needs than moving tramways. The stores moved to the job, instead of the job moving to the stores. It was exceedingly simple to arrange, and worked admirably, but he would not suggest its adoption for a production such as that with which the author was dealing. It would be agreed that a complaint should be properly and immediately adjusted. The salvage man was extremely interesting to him, because he had never met a case where an actual salvage man had had presumably nothing else to do in

the works, but he remembered a particular case where he had a suspicion that the amount of high-speed steel in the shops was far in excess of what it should have been, and he arranged one week-end to clear the whole of the shops in the works. The factory was nothing like the size of the one at Walthamstow, but he got something like three-quarters of a ton, which went into the smiths' shop and saved a lot of new material later. A good deal of waste could be prevented in that way, but the appointment of a special man for the job must depend on the size of the factory.

The relationship between employers and workmen was a matter which had to be handled very decisively. In England the relationship between the two was not what it should be, and personally he considered that the employers were every bit as much to blame as the workmen; in many cases, more so. There should be a far more open method of dealing with the men, otherwise there would still be that attitude of mistrust which was so destructive of efficiency.

Time-saving installations referred to in the paper, such as the automatic telephone, the main switchboard, and other things, were exceedingly interesting, and he hoped that most, if not all, of them would be able to avail themselves of the author's invitation to visit the works at Walthamstow and actually see these things in operation. Many of them would be able to place a more definite value on them after seeing them. It was the sense of life in the works that told them where the advantage of these systems lay, whereas it might be difficult to appreciate their value in a written paper.

Mr. Butler said he would like to criticise one or two points, and perhaps obtain a few further details. The peg control board described in the paper was quite a new system to him, but it appeared to be only applicable to a very few classes of factory. For instance, if there were a large variety of work going through the factory he should imagine that a very big department would be required to house all the boards, and the necessary staff to deal with the information would also be extensive. He could not quite understand—and perhaps the author could enlighten him—why it should be necessary, on the class of work in question, that information of the progress of the work should be required every two hours. If repetition parts of a similar nature were being made almost all the year round, and if the organisation were well arranged, the progress boards would have been satisfactory if the information had come through in reliable form once a day. Those who were troubled with progressing work had found the difficulty not so much in getting the information as in getting it reliable.

As regards grouping machinery, he agreed with the author that sufficient attention was not paid to this point in the majority of works in this country, but it was largely a matter of the class of work undertaken, and there again he felt that in many cases there were too many pieces to handle of a nature that did not occupy the machine for the whole of its time. If one could take any component or partial assembly, or even main assembly, that would keep, say, five machines busy turning out the necessary number of parts for the required output during the whole of the week, it was a simple matter to group the machines to give the finished output and arrange for dispatching it to the stores. He knew it was a system which had been developed extensively in the States, but there again the Americans had the advantage of a very big output to aid

them. When he had the privilege some time ago of going over the Ford factory in Detroit, he realised that they were past-masters in plant layout. It was almost impossible to find a job for which the material was not stored by the side of the machines, and before it moved very far it was finished, and in some cases packed in a box, with a label on it, ready for dispatch. Those were ideal conditions, and he did not think many in this country could hope for the number of parts to deal with that would enable such conditions to obtain here.

Tool demonstrators would also be an innovation to many. There might have been something of the sort attempted, but few firms had got so far, he thought, as the author's firm in this connection. He could not quite decide in his own mind whether these inspectors should be under the tool drawing office or under the rate-fixer, but that could readily be decided if a study were made of the points in connection with the work undertaken. He felt it would be a good idea to demonstrate to the machine shop, or the assembly department if necessary—if it were a case of an assembly fixture—how the draughtsman intended a fixture to be used. When he (Mr. Butler) was designing there were many instances where a tool got into the shop and on to the machine, but was not used as the draughtsman meant it to be, and in a great many cases the draughtsman designed a tool and got out the necessary drawing, but never later saw the appliance or heard how it worked.

Another thing he was interested in was the system of automatic telephones. That, of course, was a very convenient and quick system, and he was specially interested in the interconnection of the auto-call, as he would imagine it would be called, for locating an official in the factory. If the factory were of any size, and it was desired to find a superintendent, or a man in a position which necessitated him getting round the factory, it generally entailed considerable trouble to find him, and he would be interested in getting details from the author, or perhaps he (the speaker) might possibly avail himself of the opportunity of accepting the kind invitation of the author to see the system at work at Walthamstow. Was it possible to simply plug in by a system of bells on the factory inter-departmental board and find in the works the required person? Generally, with the ordinary telephone system, it gave the operators a large amount of work, and it was a very unsatisfactory duty for them to find a given man, because he might be in one of thirty or more departments. In these circumstances he could imagine that the automatic telephone system of signals would be exceedingly useful, if it were not too expensive to install and maintain. A good many firms in this country could adopt it with advantage.

Mr. Kenworthy said he had listened to a description of what he considered were the ideal conditions existing at Walthamstow, but, as had already been suggested, what was ideal there would probably be superfluous elsewhere. As a matter of fact, there was a danger of having more people actually working on the system itself than were engaged in the works. Nevertheless there were certain points in the system which could be adapted to much smaller works. One of the points on which he agreed with the author was the question of processing. He (the speaker) had been very severely criticised at one of the Institution's meetings recently for stating that the processing should be a shop job and not a drawing office job, but he agreed with the author that that should come under shop control,

either under the jig and tool drawing office or the chief rate-fixer, whichever was the more suitable. The official, however, must be a man on the productive side of the works, and not in the designing drawing office.

One other point which had been emphasised a great deal in the paper, and with which he agreed, was the importance of the rate-fixer, who, in his opinion, could do more harm in a week in the shop than any other person could do in twelve months by giving times which were too long, or which were altogether too tight, and so getting the men into such a disagreeable state of mind that it took months to rid them of it. A very careful selection was necessary in appointing the rate-fixer.

It would be interesting to learn from the author how his system of progress charts accommodated more than one batch of an article going through the shop at a time. If one were to process the job through its various operations, it meant that the checking and recording on these charts became a stupendous task, as all information for every movement of the job had to travel to the progress department. With regard to the recording of the information for that system, the author had stated that it was necessary for the foreman to place a cross against the statement, and the slip was then placed in a box, which was cleared at stated intervals for the progress department. He considered that the tendency of most of these elaborate systems was to make the foreman too much of a clerk. Generally speaking, the foreman had sufficient to do in controlling and dealing with the work, demonstrating, etc., and if he were given too much clerical work it was a great mistake, because that side of the business could be dealt with by the view room. The viewers, generally speaking, must view each operation, and then they could make out the necessary form and send it along to the progress department, which relieved the foreman of a certain amount of clerical responsibility. There was another point about the progress charts on which he would like the author's opinion, namely, what provision is made for splitting up a batch of articles in the shop? Supposing two batches of a hundred each were in the shop, one having reached its final stage, and a quantity, for some reason, was found to be scrapped. It was required to put another fifty through from the other batch that was following, to catch up the fifty that had been scrapped in the first batch. What was the system for doing that, and how was the position of that batch shown on the chart?

There was also another point upon which he would like information, and that was as to the system of chasing in operation. In the shops with which he had been associated there was a system in vogue which had a great many failings. When there were special machines for each operation there was not much trouble, but when there were different operations on the same machine it was a case of which operation should be done first. Very often the chaser gave the wrong information. This, however, was an internal matter, which each shop had to decide for itself.

With regard to the grouping of machines, he personally considered that to be very much of a mixed blessing. Where the output and the size of the shop justified it, it was probably an ideal system, but personally he had found it to be rather difficult on a small scale. He had a part of his shop grouped, and a part not grouped. The part that was grouped was for the larger components, and he generally

found that these components got through very quickly to the stores department, but even when they had one part of a shop grouped in that way there were very often operations on the components which had to be done elsewhere. It might be necessary, for instance, to sand-blast a casting before it could be machined, and they could not have a sand-blasting machine amongst the grouped machines. Another of the intermittent operations might be a hardening operation. That necessarily had to go to the heat treatment department. These were the difficulties which, of course, had to be surmounted in regard to the grouping of machines.

MR. MARSHALL said the idea of the peg board had already been adopted, and even developed further than had been suggested in the paper in connection with motor-car construction work. He took it that the author divided the machining jobs into different operations and simply progressed them successively. That could be carried a step further by dividing the construction into stages and simply calling them operations. For instance, with a motor vehicle they started with the frame, and perhaps had the front wheel and axle assembly, then the rear axle assembly, differential, gearbox, etc., perhaps getting twenty stages. By treating these as operations and progressing them by pegs in the different holes they got a very good idea of the actual assembly production which the charts did not show to the same extent, and charts themselves were not so easy to maintain.

The question of motion study was one of extreme interest. We owed the Americans a great deal in doing pioneer work in this connection, but to a certain extent they had "cut their own throats." Taylorism or scientific management had become so detested among a majority of the workpeople, owing to its misapplication, that a Bill had actually been passed through the House of Representatives in the United States forbidding the entry of a stop-watch into a factory—showing how a perfectly legitimate action came to be regarded with most unjustifiable distrust. That was due to the attitude taken up by employers, because simply in the quest of the almighty dollar they had considered output, and not considered the human machine at all. They had improved their machines out of all knowledge, but what attention had they paid to the man himself? The application of industrial psychology was too big a subject to comment on more than briefly on that occasion. Whole papers could be written on it, but some interesting facts were available in regard to the methods of carrying out work and of selecting workers, and these principles could not be ignored. In many cases the application of such methods had increased the output out of all recognition. For instance, an experiment was carried out at the Bethlehem Steel Works in relation to the carrying of pig-iron. The normal load of a man was 12½ tons per day, and the man knocked off at 5.30. The experiment was that the man should work for 9 minutes—4½ minutes carrying the load and 4½ minutes coming back empty—and then should rest for 1½ minutes. By that system they increased the output of each man from 12½ tons to 47½ tons, and a new man who had not worked at this job before was able to carry his 47½ tons before 5.30. Another interesting investigation was an analysis of a bricklayer's movements. It was found that he made 18 movements in the laying of a brick, and this was reduced to 5 simply by re-arranging the position of the

bricks and the mortar with which he worked. Incidentally, it was mentioned by the speaker that the trade union number of bricks which a bricklayer was allowed to lay per day was 275 in the towns and 375 in the country. Why the number should be larger in the country than the towns he did not know, but a town bricklayer was able to lay 370 bricks per day on the system he had indicated.

With regard to the selection of men whose duty it was to see the work through the shops, if more attention were paid to this and in the supervision of even minor difficulties, the relations existing between employers and employed would be greatly improved.

The elimination of waste motion entails a considerable amount of careful research, but the results obtained by it cannot be ignored. The man who has his tools handy is a much quicker workman than the man who has to search for them, hence the replacement of acts of decision by those of automatism results in an immediate stimulus to output. The following is a typical instance:—

Job: assembling a braiding machine; parts originally kept in box or put on floor near a low bench. Factors considered: (1) Handiness of loads (parts); (2) sequence of parts; (3) handy and orderly arrangement of tools. The tools were all arranged on tables or hooks and the former points attended to. Result: output was increased from 18 to 66 units per day.

The main point to keep in view in applying any psychological principle is that where workmen are giving satisfactory results there should be no interference, and that considerable tact should be exercised in introducing any innovation.

Mr. Black said he thought it only fair to point out, in regard to the remark of the last speaker as to the stop-watch in America and the position of scientific management, that the question referred to occurred in connection with the Watertown Arsenal. There was a good deal of political jobbery in connection with that, and what the last speaker had said was not a fair description of what really happened. Labour interests got hold of certain representatives, equivalent to our M.P.s, and insisted that they raised the question in Congress, alleging that scientific management speeded up operatives, resulting in overworked men and a great increase in accidents, until American workmen performed two or three times as much work as the workmen of other countries, with the concomitant result that the ratio of accidents was from three to four times as high as in other countries, and that workmen were reduced to automatons.

In reply to this the Senate Committee, reporting on March 9th, 1912, found that "neither the Taylor system, the Emerson system, the Gantt system, the Brombacher system, the Stimpson system, nor any of the systems so called scientific management, have been in existence long enough for your committee to determine with accuracy their effect on the health and pay of employees and their effect on wages and labour cost. The conclusions we have arrived at are all based upon what we consider to be the logical sequence of the conditions existing or proposed. The selection of any system of shop management for the various Government works must be to a great extent a matter of administration, and your committee does not deem it advisable nor expedient to make any recommendations for legislation upon the subject at this time."

With regard to alleged increased accidents, the records of the American War Department show that the percentage of accidents in Government plants among those working under the premium system is less than those engaged on day-work.

The opponents of scientific management, however, did not allow the matter to rest with the report given above, and succeeded in tabling a Bill in the Senate, entitled "The Tavener Bill," to prohibit time study, the use of the stop-watch, and other accompaniments of scientific management in Government works, and the fresh Committee which were appointed were taking evidence in 1916, but the entry of the U.S.A. into the world-war gave them something else upon which to expend their energy.

In conclusion, it would appear that all opponents of what may be termed "common-sense scientific management" appear to lose sight of the fact that neither the Taylor system nor any other system determines rates of pay, which, after all, is the thing that counts, and which is a matter wholly independent of any system of management, being the subject of either collective or individual bargaining.

MR. PATTINSON, replying to the discussion, first dealt with the point raised by Mr. Scaife that he had not mentioned the metallurgist. In the Walthamstow works the metallurgist was not regarded as being on the production side. They had their laboratory and chemists, but their metallurgist was a consultant whom they called on periodically.

With regard to the relationship of the staff and charts, details could not be given on that occasion, because, as was well known, the view-room superintendent was more or less on an "isolated island" as regards production in relation to his colleagues, but he would be very pleased to communicate to Mr. Scaife full details. As to Mr. Scaife's remarks concerning the rate-fixer coming under the jig and tool department, he did not quite agree with him. It was not his intention to say, if he had done so in the paper, that the rate-fixing department should come under the jig and tool department. His point was that they should be in close contact, but at the same time he was not at all sure that it would not be a good plan to put the rate-fixers under the jig and tool department, because in one part of the paper he had stated that the demonstrators should substantiate what was contemplated theoretically by their brother department, the rate-fixing department, and therefore he was inclined to consider it would be a good thing to have the rate-fixing department under the jig and tool department. Demonstrators did not come under the rate-fixing department; it was not intended that they should. To his mind, they should essentially come under the jig and tool room design superintendent. It would appear to him absolutely imperative that this should be so.

As to Mr. Scaife's remarks concerning the peg control board, it was not intended to go into minute detail and show exactly what was happening per batch or part of a batch. If there were a batch of fifty, and it was known that, say, one dozen was rejected, it would really make it very complicated to show that on the board and record all those little things which happened in the course of machine-shop production. The reason it would be complicated was because there was a very considerable number of parts passing through the works at Walthamstow, and it was really the complex nature of the production which led to the introduction of

this board. Moreover, it was necessary to know the position every two hours, and not every twenty-four hours, as had been suggested. It was indeed highly desirable to know the position at frequent intervals, and it was necessary to watch and see that there was the least delay possible. The boards were developed in such a manner as to show when the job was waiting for material, etc., and then to record the progress of the batch from the time the material was received. The work was scheduled to leave the factory at a certain time, and if it did not, then there was trouble. The whole object was that the board should illustrate what the position was, but where scrap had occurred, then this was not shown on the board until the scrap reached the stores. There was a column at the end of the board, and if a dozen had been scrapped out of fifty, then thirty-eight were shown as being received into the stores, and the planning department then had to take steps immediately to issue another order.

Mr. Bell had referred to the danger of over-systematising, and rather suggested that they were guilty of this at the Walthamstow works. The fact was that all the schemes which he (the author) had described in the paper had amply justified themselves up to now, and if they did not, then the management was quite ready to scrap them.

As to demonstrations before the shop stewards and management, he had received all kinds of excuses as to why certain things could not be done, but he had been able to prove that they could be achieved, and the shop stewards and others had confessed their surprise, but once they were shown how, then things went quite smoothly. That was the only successful way of 'bringing it home," so to speak.

With regard to moving stores, he did not think the scheme suitable for a factory such as that at Walthamstow with so many parts going through.

As to tools lying about the factory, he had found the same thing, and had now arranged that a man must return an old tool before he received a new one. That had been found desirable in order to keep a check on the amount of tool steel in the factory.

As to Mr. Butler's comments on the peg board, he had already mentioned why it was necessary to have the information every two hours and not once in 24 hours. Even then, by the time the usual paper records reached the progress department, it pretty well absorbed the 24 hours. That was why it had been found absolutely necessary to be conversant with the position in the shops continually, and it was of immense value in the case of parts which were wanted desperately and to a given schedule.

As to the auto-call, he would be pleased to show anyone the system working who cared to come down to the works. He had found it an exceedingly efficient and reasonably cheap job, and from the opinions expressed by those who had had experience of the light system, with which he had never been conversant, the auto-call, as installed at Walthamstow, was far preferable.

With regard to Mr. Kenworthy's observations as to the rate-fixing department coming under the process department, as he (the author) had already said, he was not at all sure that it should not come under the jig and tool department, but, taking all things into account, he thought the process department should come

under the rate-fixing department, because after all the rate-fixer should surely know all about the process work, otherwise he would not know how to get his time settings and so forth. Mr. Kenworthy had said that the foreman should not be burdened with too much clerical work. To a certain extent it was agreed that the less clerical work the foreman was called upon to do the better, but at the same time, in a case like this, where all that was necessary was to put a cross against the control board statement, it kept that official absolutely conversant with the work which was under his supervision and which was committed to schedule. It was one of those automatic reminders which indicated when the work was finished, or when the batch was finished, and it was felt that it was a help rather than a hindrance that the foreman should do this. Mr. Kenworthy had questioned the system of chasers at Walthamstow. There were a few chasers about the place, which was very necessary in a large factory, and certain units were allocated to one chaser. It had been found in practice that on requesting a chaser to locate in the shop a certain part, say, belonging to a gear-box, he would take the inquirer into the shop and show the part, which might be under operation in grinding. If it were needed to find another part connected with that box, it would probably mean that that chaser was not working upon that part, and it was necessary to find another chaser. Therefore it had been decided to allocate one unit to one chaser.

As to Mr. Marshall's suggestion that stop-watches should not be exhibited, personally, if he (the author) were in the shop, and if the time limit were in dispute, there would be no exception to a man coming, quite above-board, and pulling out his stop-watch. There did not appear to be anything to be ashamed of in working with stop-watches, because it was necessary to get down to the root of the trouble in some way when there was a dispute. Men were asked to clock on when they came in, as a record that they were there, and it was just as desirable to be sure that the time setting was correct or otherwise by checking it with a stop-watch. Very often the mere fact of pulling a stop-watch out, if the operator was at fault, and had been guilty of dilatory tactics, was sufficient to settle the issue.

In conclusion, the author had a slide projected on the screen which showed a machine operating on four rear-axle casings at one time, at the production rate of two hours each. The machine had been installed at Walthamstow for four years, and this time had been regularly attained. Judge the surprise when he (the author) visited two other well-known factories and found that in one instance one week was the time taken, whilst in the other four days was needed, to machine a similar casing, which had been produced elsewhere in two hours per unit over a long period. It pointed the moral and illustrated how desirable it was for production engineers to confer at such meetings, so that their views and experiences might be pooled.

COMMUNICATIONS.

Mr. Pattinson is to be congratulated upon his paper on "Works Organisation" recently presented to the Institution of Production Engineers.

The writer concurs that the rate-fixing department should be considered as one of the most important units in the organisation of a factory, although it is to be feared that this is not usually sufficiently realised by the managements of British engineering enterprises.

It would be interesting to have the author's views on the subject of time study, and, if possible, further detailed information as to the methods employed for arriving at the times allowed. It is assumed that, in the case of the large organisations referred to in the paper, a system of time and motion study has been adopted for the purpose of time-fixing.

In dealing with the problem of scrap the chart system described is commendable, as also the provision made, by the appointment of a "trouble investigator," for the purpose of investigating and settling difficulties relative to production.

There are one or two points on which the writer would welcome further information.

The author advises, for example, that "the rate-fixing department should be in constant touch with the estimating and cost office. Any increases in time limits, etc., should be recorded instantly in both the departmental records. It would be deplorable to find the estimating department computing work at a certain figure when that figure was based on months old records of the rate-fixing department, which in the interim had found its time limits were too 'tight,' and had raised the time without notifying the estimating department."

Would not the correct procedure require that prices for estimating be based on the cost office records of actual results obtained?

It is common knowledge that the time allowed for a given piece of work may not represent the actual time taken; it is quite feasible that this could be either less or more than the time scheduled. The actual time taken would appear to be the correct basis on which to calculate for estimating purposes.

It is agreed that the records relating to time allowed should be kept up to date for the cost department.

In the opinion of the writer, processing should fall within the duties of the rate-fixers, as, apart from the jig and tool drawing office, the author has previously mentioned that the rate-fixing department should compute time settings and draw up the schedule of machine allocation, which duties are very closely related to processing. It would, no doubt, be sufficient for the head of the rate-fixing department—that is, the production engineer—to supply the jig and tool drawing office with a copy of the processing sheet of

operations, and to guide their efforts with regard to the requisite jigs, tools, and fixtures.

The author refers to the convening of a weekly committee, comprising a representative of the management, the machine-shop superintendent, the view-room superintendent, and the jig and tool superintendent, for the purpose of investigating the causes of scrap, to consider steps for preventing a recurrence, to correct errors in jigs and tools where necessary, and to have the opportunity of hearing the case of the operator, if desired. For determining who is responsible for scrap, this procedure would appear to be too costly to justify its adoption.

With respect to the monthly scrap chart, it is stated that the loss in scrap and productive hours attributable to defective supervision shall be investigated by the management, a notification being sent to the superintendents concerned a few days before the case is deliberated upon in order that they may have an opportunity of disputing the charge.

This appears to be a very unsatisfactory method, since the causes have already formed the subject of investigation by a properly constituted body, thus rendering unnecessary further disputation.

In the view of the writer, the system outlined below solves the problem, and does not entail a fraction of the expense incurred by the summoning in conference of a body of high officials. The scheme is this: in performing an operation in the machine shop, any abnormal conditions, defective tools, or bad materials will, of course, be reported to the foreman by the operator, whose bonus would be adversely affected. The foreman should then, in turn, record the facts on the bonus ticket or progress label. When the parts are taken to the inspection department the reviewer or inspector dealing with the item will call the attention of the foreman, who will inform the inspection superintendent, who should be fully competent to make a decision with regard to the direct cause of scrap. Before a decision is given the foreman or superintendent responsible for the operation can readily be called into consultation, and the bonus ticket and progress label, or any other form used, could then be signed accordingly.

In any case, it is not usual for an operator to be paid for scrapped work for which he is personally responsible. Suppose, for example, there were 100 castings machined, 20 of which were scrapped, it is usual for provision to be made on the bonus ticket, such as "Pay bonus on 80 only," and allowance to be made for scrap due to any other cause.

In the system outlined by the author it would appear necessary for the bonus earned by the operator to be held over pending the decision of the weekly committee, or even the monthly investigation by the management, since, if responsibility for scrap were disputed after one month and the decision reversed, the operator's bonus for that operation might be affected.

Would it not be preferable to make a decision on the spot, so to speak? The cause of scrap usually falls within these categories:—(1) Purely operator's fault; (2) due to negligent supervision; (3) to jig, tool, or machine defects; (4) to bad material and (5) to faulty inspection on a previous operation.

It should be possible for an unbiased investigator to definitely decide the majority of cases brought before his notice without the

management resorting to the expense of convening set conferences. Could not the "trouble investigator," who is endowed with sufficient authority to alter a pattern or drawing, decide this question?

G. H. HALES, M.I.P.E.
(Member of Council.)

Guildford.

Replying to the letter of Mr. G. H. Hales, which appeared at p. 166 of *Engineering Production* for February 16th, the writer appreciates the interest shown.

Whilst it is not claimed that finality has been attained at the Walthamstow works in time and motion study, a sample time-setting card is submitted below, which the writer considers to approach the ideal.

The formula used on this card is:—

$$\frac{Length\ of\ cut \times feed \times number\ of\ cuts.}{Revs.}$$

It is obvious, of course, that the key to time study is the cutting speed, which is dominated by the steel specification. The precaution must also be taken to ensure that the shops are supplied with the brand of tool steel that can be relied upon to attain the stipulated cutting speeds. Reasonable allowances for spring in the job on account of excessive length, and other contingencies, must also be provided for by the rate-fixer when making his time study.

In demonstrating the operation, the rate-fixer should check the demonstrator by watch observation, and the actual figures obtained should be inserted in red ink over the estimated figures. On the back of this operation detail card should also be recorded every alteration that is made in the operation during the course of production.

Mr. Hales states that he is not quite clear on the writer's observations regarding the necessity for the rate-fixing department being in constant contact with the estimating department and cost office. He writes: "Surely the time limit would not be used for estimating purposes in such circumstances, but rather the cost office records of actual results obtained, and that the actual time taken would appear to be the correct figure for estimating purposes."

Mr. Hales' suggestion certainly appears the most logical, but suppose for example, the cost of manufacture of a certain steel casting was estimated at, say, £8, this figure being based on good material and no machining trouble. A further consignment of these castings is delivered, but owing to bad material the next batch costs nearly double; therefore, to cover the operator, who is not to blame, he is given a plus allowance for bad material. This plus allowance would not be recorded on the operation detail card because this card would record ideal time studies. The extra cost attributable to bad material would therefore only be truly recorded when the job was finished, and the records reached the cost office. Now this bad material question has been known in practice to go on for years, therefore, one is bound in these circumstances to have a fluctuating figure. This is the point; perhaps it is decided, owing to high pressure in the factory, to obtain some of these castings finished complete by outside firms. One must, therefore, assume and hope that the material would be good, and base the comparative

estimate on what should be, and not on what has been one's misfortune.

It is quite possible that during a certain period some newly engaged labour may have been operating on this work, and, owing to inefficiency, made debts. This, again, would result in an unreliable figure.

It is agreed that it would appear sufficient for the head of the rate-fixing department to supply the jig and tool department with the process operations, and to guide their efforts with regard to suitable jigs, tools, fixtures, etc. Under ideal conditions, where good material can be relied upon, the writer concurs with the remarks of Mr. Hales, but unfortunately these conditions do not obtain to-day.

OPERATION DETAIL CARD.

NAME OF PART	MATERIAL	PART No.
MAGNETO DRIVE BRACKET. "S" TYPE. (GUN METAL)	Alloy No.4.	A.19302.
OPERATION No 1. FACE FLANGE AND TURN SPIGOT.	DEPT 26	MACHINE Centre Lathe.

DETAILS	TIME Mins. Secs.	DETAILS	TIME Mins. Sec
Pick up and Set in Chuck.	36	B/F.	9 57
Start Machine.	3	Stop Machine.	3
Index Tool Post.	6	Dismantle Job.	30
Chamfer Bore for Centre.	30		10. 30
Bring up Tailstock and apply Centre.	30	Gauging.	30
Index Tool Post.	6	Tools.	30
Set for Facing.	30		11. 30
Face 2.6 x 1 x 66 ÷ 68	2. 30	Plus 10% Fatigue Allowance.	1. 9
Turn Register .3 x 2 x 80 ÷ 68	42		12. 39
Face Register .3 x 2 x 66 ÷ 68	36	Plus 60%	7: 35
Index Tool Post.	6		20. 14
Finish Turn Register. .3 x 2 x 66 ÷ 68	36	Operation demonstrated. Date. 25-10-1921.	
Finish Face 2.6 x 1 x 66 ÷ 68	2. 30	Actual time by watch observation. 20 mins. Signed.	
Face Register .3 x 2 x 66 ÷ 68	36	Machine No. 351.	
C/F	9.57		

ACTUAL TIME Mins. Secs 10. 30.	TIME LIMIT 20 mins.	Cutting Speed. 120'	DATE 1-9-1921.	SIGNED

Back of card

ALTERATIONS					ALTERATIONS				
FROM	TO	REASON	DATE	SIG.	FROM	TO	REASON	DATE	SIG.

Mr. Hales mentions what he considers an expensive method of determining who is responsible for the scrap, and states that the scheme outlined is an unsatisfactory one, since the causes having been truly determined by an authoritative committee, it is difficult to justify any further disputation. The writer would point out that experience has proved that the short time spent by this committee is well worth while. It must be borne in mind that the committee are inspecting scrap representing the dregs of the factory production. In addition to affording the opportunity of actually arraying the scrap for the benefit of the persons concerned, it enables the superintendents and foremen to pass their opinions on the spot with regard to such matters as jigs, tools, processes, tolerances, etc., and the

remedy can be promptly devised. To deal with the scrap and have a minute investigation as it occurs, would be impracticable in a large works. In serious cases, of course, immediate steps have to be taken. There would be no holding over of bonus earned by the operator, as suggested by Mr. Hales, pending the decision of the monthly investigations by the management.

The monthly investigations must not be confused with the activities of the weekly scrap committee. Their results would be recorded, and where negligent supervision is found, it would be noted on the monthly chart. It is far better to do this than to leave to the memories of the members all those cases that may have come under defective supervision.

Mr. Hales also writes: "Could not the 'trouble investigator,' who has sufficient authority, decide this question?" As was stated in the paper presented by the writer, the "trouble investigator" does represent the management. At the same time, all the other superintendents concerned are on the scrap committee, and this certainly does make them alive to their responsibilities, and results in the responsibility being allocated to the right department.

T. E. PATTINSON, M.I.P.E.
(Member of Council.)

Walthamstow.

The subscriber feels compelled to write thanking Mr. T. E. Pattinson for his admirable paper on "Works Organisation."

It is the most sensible, instructive, and broad-minded lecture which the writer has had the pleasure of reading for some time.

The tone of the author's generalisation on page 126 of *Engineering Production* for February 9th is splendid. It is felt that industry would benefit considerably if there were a few more men in it like Mr. Pattinson. "Industry," in this case, includes everyone, from the employer down to the messenger boy.

W. J. BILTON.

Upper Norwood, S.E.19.

THE
INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting was held at the Institution of Mechanical Engineers, London, on Friday, February 24th, 1922, Mr. Max R. Lawrence, President, being in the chair.

The minutes of the previous meeting were read and approved.

The President briefly reported on the provincial meetings held at Newark on February 13th, and at Coventry on February 14th.

Mr. G. W. Eastwood then presented his paper on the subject of "The Efficient Production of Automobile Bodies."

There was a large attendance, visitors being present from the Institution of Automobile Engineers and the Institution of British Carriage and Automobile Manufacturers.

Mr. Eastwood's paper evoked an interesting discussion, in which a number of the visitors took part.

THE EFFICIENT PRODUCTION OF AUTOMOBILE BODIES.

By Mr. G. W. EASTWOOD, M.I.P.E., Superintendent of the Body Building Department of Messrs. Arrol-Johnston, Ltd., Dumfries.

The efficient production of motor car bodies has not always received the consideration that it deserves. In fact, there are many engineers who treat coachbuilding as quite beneath their serious consideration, but there is no doubt that motor car body production is of vital consequence in these days, and is rapidly becoming an important branch of the engineering profession.

Some few years ago one of the vital questions occupying the minds of the chief executives of our large manufacturing concerns was that of mass production. To-day we are told on the one hand that we have over-produced, and that in consequence there is too much unemployment. On the other hand, we are informed that it is necessary to produce more, and also to export more, if this country is to regain her former position in the commerce of the world. However, the subject of these notes deals not with the politics of the industry, but with the efficient production of motor car bodies, having particular reference to jigs and similar equipment.

Whether efficient production is another name for batch production, quantity production, repetition production, or standardised production, the author leaves for others to decide. Certain it is that the most efficient production can only be obtained by adopting the best methods, taking into consideration all the circumstances of the case, and circumstances vary considerably with the coachbuilder. There is no doubt that the history of coachbuilding has a material bearing on the position to-day.

If we go back to the earliest days of civilisation, the craftsmanship of the coachbuilder looms large—there are the chariots, sedan chairs, and vehicles of wonderful and ponderous design as typified by the old stage-coach. Comparing these ancient works of art with the modern motor car chassis, the contrast between the work of the artist and the engineer is indeed striking. The art and craft of the coachbuilder is evident right through the ages, so that it should be a matter for no surprise if some of the methods employed to-day are antiquated.

The motor car consists of two essential parts—the chassis and the body—and from the viewpoint of the coachmaker, the body is the more important. Body construction demands equally

skilled craftsmen, and a wider range of material has to be handled than in the case of the chassis. As one prominent coachbuilder recently observed, the business is scientifically intricate, and with a dignified charm is variegated and artistic, and the problem of laying down any hard and fast rules in order to produce mechanically a work of art has first to be solved before the difficulties can be fully realised.

The type of workman met with in coachbuilding establishments differs considerably from that found in the engineering shops. Contrasted with coachbuilding, engineering is comparatively young, and, moreover, its often attractive possibilities appear to draw the more ingenious and adventurous of our young men. To quote an old adage—" Nothing venture, nothing win," and not only has the engineer ventured but he has won, and he is to be congratulated on the enterprise he has shown. The success he has attained has stimulated others. It is undoubtedly true that the method of building bodies to-day has been influenced to a great extent by the methods so successfully employed by the engineer. The engineer's methods have been copied, especially in coachbuilding factories, where the body is manufactured side by side with the chassis on which it ultimately has to fit.

It is seldom, however, that the coachbuilder has the opportunity to adopt the highly efficient methods he would like, for he rarely, if ever, has the chance to produce in such large quantities as his colleague, the engineer.

For example, the scheduled programme of a firm may call for the manufacturing of a thousand chassis, all of a given horsepower. The last chassis will be exactly like the first—every nut and bolt, every component, and every unit will be as near alike as human ingenuity can devise. In order to meet the needs of a wide market, however, it will be necessary for a number of these chassis to be fitted with a two-seater body of the cosy and comfortable type; others will be furnished with a racy type of body; whilst others may be provided with an open four-seater body or a coupé. It may be a saloon, an all-weather, a limousine, a landaulette, or a cabriolet. In fact, it is difficult to find sufficient names to designate the types of bodies that are manufactured to-day, and coachbuilders themselves are even at a loss for words to describe their own productions. The types of bodies enumerated refer only to the pleasure car. It must be remembered, however, that the same chassis may also be used for business purposes, and it is possible to extend the already varied range by fitting lorries, vans, taxicabs, and other types for commercial use.

It may be considered ridiculous to assume that chassis can be successfully built for all these various types of bodies, either for pleasure or industry without some alteration to the gear ratios or gearboxes, in order to render them suitable; but it is a fact that there are many cars on the road to-day that have com-

menced their careers as luxurious pleasure cars only to finish their days as humble delivery vans. These examples will show that the coachmaker has, compared with the engineer, few opportunities to engage in repetition work.

It will be assumed, nevertheless, for the purposes of these notes, that there are sufficient bodies of one type to build to justify laying out the job on efficient lines. It will be presumed that the bodies will be built by coachmakers who have had a coachmaker's training, and not by engineers who are accustomed to working to blue-prints and to very fine limits. It will not be overlooked that the body is to be produced complete and mounted on the chassis at the lowest possible price. It will be conceded that the motor car is not complete until the body is on the chassis, and that the body is no mere accessory.

Frequently one will hear, particularly after a popular automobile show, that there is a good market for a certain type of car, providing the price is low enough to compete with some other type already existing. Let us assume that there would be a good market for a luxurious 50 h.p. car at, say, £500. A group of engineers confer, and it is decided to produce it. Before operations are commenced, the selling price is fixed, and a schedule is drawn up of the necessary material for the production of the chassis. The labour costs and other expenses are added, and the difference, if any, is allocated to the production of the body. It often happens that there is nothing remaining, and the coachmaker is expected to produce a body and show a profit!

The point the author wishes to make is that it is a serious and difficult problem to make a car body that will suit all classes of the buying public under the conditions obtaining. It is also desired to emphasise that quantity production does not mean shoddy production; that a standard of either good or bad quality can be produced, irrespective of the methods employed or the quantity put in hand.

A firm's standard of perfection need not be affected by quantity production. It is advisable to remember that, if by adopting a certain method or a certain tool or jig the result is the saving of 1d. per body, in the production of 1,000 bodies the saving will be £4 3s. 4d. Carry this argument further, and consider the vast number of operations required to produce a motor car body. If the merest fraction of a penny per operation can be saved, the ultimate result may mean all the difference between success and failure.

Serious consideration of the most minute details is more necessary when dealing with large quantities than when dealing with a single article. The greatest care should, therefore, be exercised in order to avoid errors, and to draw up a well-thought-out production programme before operations are commenced. One thing is certain—efficient production and an alteration of pro-

gramme in the midst of production are a contradiction in terms. It is better to adopt Ruskin's rule, " First make up your mind what you are going to do, then do it."

In all factories and workshops the general layout of the plant, machinery, and equipment, the organisation and administration, the acceptance and storage of raw material, the work in progress, the buying of the raw material, and the delivery dates for the finished goods are, or at least should be, arranged according to a given programme. These are matters of vital importance to efficient production, and demand so much time and consideration that this aspect of the subject would need a whole evening for discussion. Since in these notes we are more concerned with methods of manufacture, those important points will have to be left for consideration at some other time.

The general outline of a body is usually first decided upon,

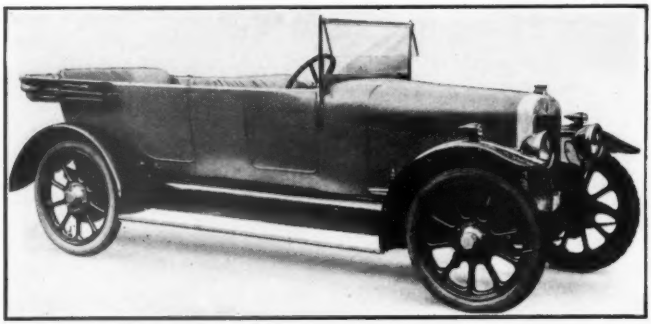


Fig. 1.—An example of a body produced in large quantities.

taking into consideration the finished car with its full complement of wings, running boards, bonnets, screens, and hood, according to the chassis to which it is to be fitted. The body selected for illustration in fig. 1 is chosen not on account of its beauty or its general outline, as outline and design always did and always will alter according to the demands of the public, but is shown because large numbers of this particular type of body go through the works. Although this illustration is from a photograph, a rough and ready sketch is generally the first attempt to convey the information or idea to the mind of the coachbuilder. A body of this type is modest when compared with many others of the all-weather and saloon type produced in the same factory, but the illustration serves its purpose inasmuch as it will help one to distinguish its various components in the illustrations which are to follow. As already indicated, the coachbuilder cannot always dissect all the parts used in the con-

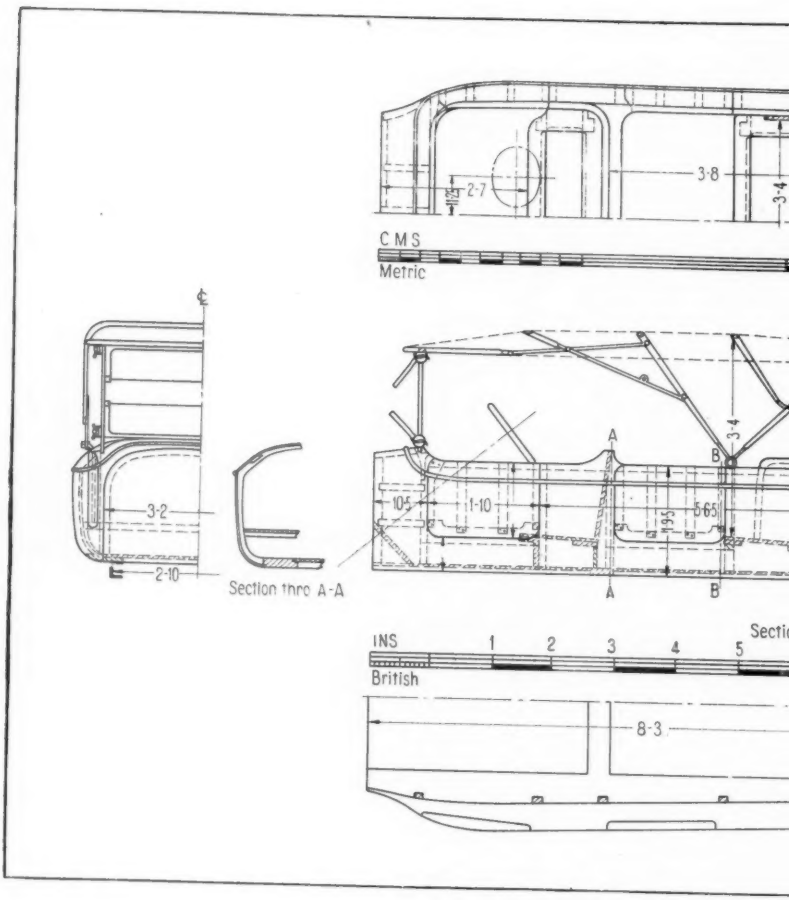
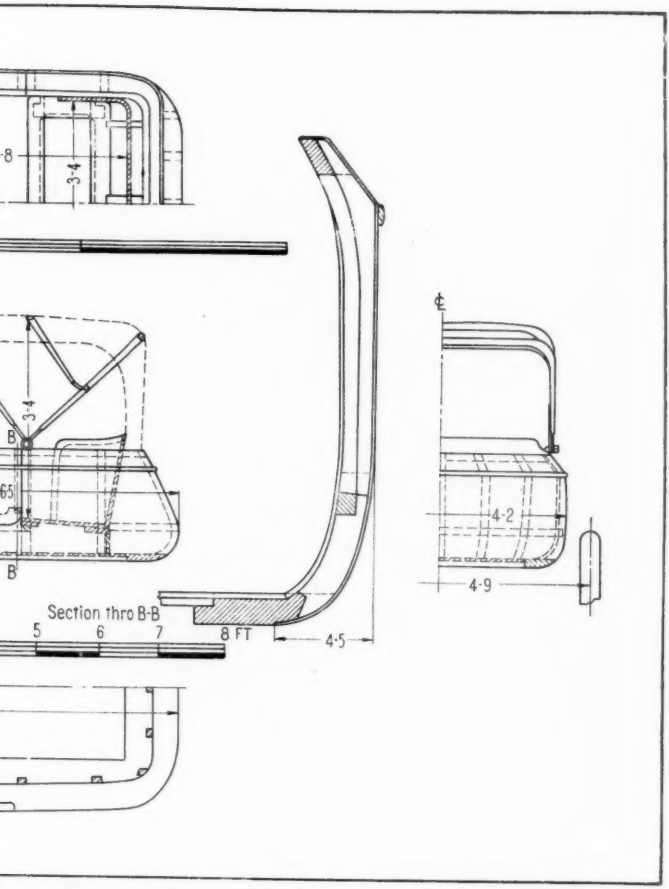


Fig. 2—An example of a worki



f a working drawing.

[*To face p.* 243.

struction of a body and make blue-prints of them to which operators can work.

A more general procedure is to make a full-sized working drawing, a half-plan, and in elevation, as illustrated in fig. 2. The working drawing is often set out on a board, known as the cant-board. The elevation is made on a large sheet of paper, and very often pinned to the workshop walls in a convenient position for the operator. This is invariably the case when one body only is required or where the body is to be the forerunner of many others of a similar type.

The method found to be successful and employed by the author, and which he has to confess has been copied from methods learned in an engineering establishment, is first to make one of these bodies and try it out in every detail. Just as the engineer has a pattern made from which he will ultimately make moulds and from the moulds will obtain parts in any quantity, the first body can be used as a pattern from which moulds and jigs can be made.

The method of construction of a car body differs considerably in various countries and also in various parts of Great Britain. Not only is price a governing factor, but opinion differs—as it always will—as to which is the best method. Whilst some will declare that a car body built entirely of steel throughout is the best, others will be equally emphatic that an all-aluminium body is unsurpassed.

The generally accepted practice, however, in this country is a combination of wood and iron suitably upholstered and finished, the main framework or skeleton being constructed of timbers afterwards covered with sheet steel of the correct contour.

The body under discussion is assumed for the purposes of explanation to be merely a pattern from which many others will be produced, and each part will be dissected—each piece forming a model of what others will be like.

It has been found to be sound practice, again to adopt a method similar to that employed by the engineer in giving each part a number, this preferably before the body is dissected. The system of numbering may be carried out to coincide with the general principle obtaining in the administration of the factory.

Those who intend to carry out this system are advised to use letters in addition to numbers, as, by adopting one letter for all the parts for one type of body and another letter for a different model, the patterns are easily distinguished if at a future date they should become confused. There is one particular member, known in some parts of the British Isles as the "bottom side," designated in America the "sill." This has been numbered part A2 in our scheme, and reference will be made to this later. The door is a complete unit, and an illustration of this is given subsequently.

It is necessary to draw up at this stage some definite manufacturing system, as once the parts are in circulation through the shops and large numbers have been machined ready for assembling, unless some predetermined schedule or key is available for reference, chaos will result.

For the sawmill or body shop a simple chart, with three columns headed " Component," " Part No.," and " Description," may be devised. Under " Component " there would be, say, the " bottom frame " with part numbers A_1, A_2, A_3, etc., which will indicate in the description column " Right bottom side," " Left bottom side," " Rear bar," and so on respectively.

A more elaborate chart has six columns headed " Component," " Part No.," " Description," " Stores No.," " Bin," and " Compartment." Such a sheet, although more detailed than the previous example, is much to be preferred, as, in addition to identifying the parts, it indicates where the details are to be found.

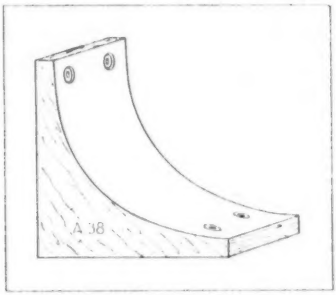


Fig. 3.—A typical part manufactured in large quantities.

In some establishments a definite sequence of operations is drawn up for each part, and drawings are made in some cases showing the measurements and tolerances. In fig. 3 is illustrated a sample part, whilst in fig. 4 is shown a typical operation sheet. It will be seen that no fewer than eight operations are necessary in order to produce this very simple-looking part. Each operation is specially laid down. The particular cut to be made is shown in very thick lines, but as there are often as many as from 250 to 300 wood parts alone in a car body, and this particular one is of a simple character, the majority requiring a far larger number of operations to complete than this one, it will readily be appreciated that only in the event of a considerable number would this course be justified.

Where it is desirable and profitable that a definite sequence of operations should be followed, a simple chart can be devised for cases where there are, say, 5,000 bodies of one size and type.

The operation sheet will have three columns headed "No.," "Operation," "Machine."

No. 1 operation will indicate "Select material," and in this case "Ash" will appear in the third column;

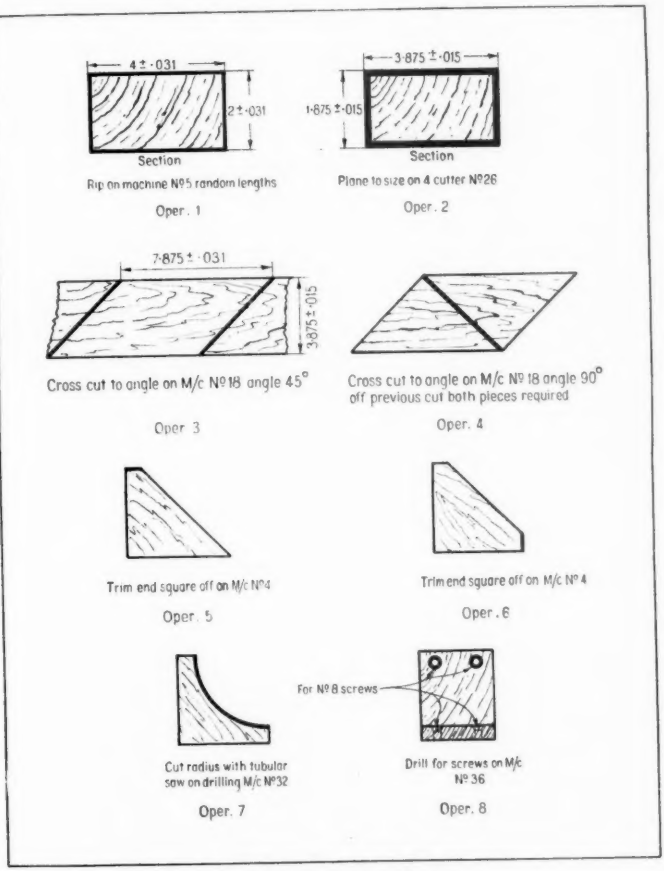

4 ± ·031
2 ± ·031
Section
Rip on machine No 5 random lengths
Oper. 1
3·875 ± ·015
1·875 ± ·015
Section
Plane to size on 4 cutter No 26
Oper. 2
7·875 ± ·031
3·875 ± ·015
Cross cut to angle on M/c No 18 angle 45°
Oper. 3
Cross cut to angle on M/c No 18 angle 90° off previous cut both pieces required
Oper. 4
Trim end square off on M/c No 4
Oper. 5
Trim end square off on M/c No 4
Oper. 6
For No 8 screws
Cut radius with tubular saw on drilling M/c No 32
Oper. 7
Drill for screws on M/c No 36
Oper. 8

Fig. 4.—Operation sheet.

No. 2.—Cross cut rough length—pendulum saw;
No. 3.—Surface one side—under and over machine;
No. 4.—Thickness—under and over machine;
and so forth. Such a sheet not only enumerates the various

operations the blank must undergo, but also indicates the machines to be used in order to complete the cycle of operations. The usual procedure is to hand to the operator in the timber shed, who is selecting the material, one of these operation sheets, together with an indication of the model required, and also a progress note which states the number of pieces to be manufactured.

In fig. 5 is illustrated the piece previously referred to as "A2." This is a part on which bottom machinery can be used to considerable advantage. It should be observed, as the two sections show, the part is of given section, and it is cut to a definite length. A series of notches or recesses cut on one edge will ultimately receive the standing pillars, whilst mortises are also cut at given intervals on its side to receive the cross members. At one end a tenon is also made.

As to machine equipment, a chain-feed multiple cross-cut saw bench can be employed to considerable advantage. The rough planks when placed on the bed of the machine are pulled past the three circular saws by means of poles fixed on a drag chain.

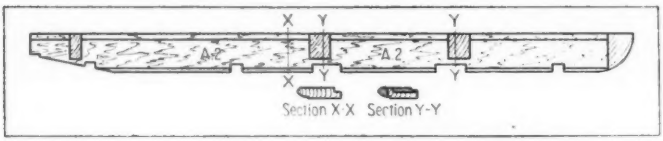


Fig. 5.—A typical motor car body member.

It may be added that an efficient truck system is essential in order to cope with the rapid output from a multiple sawing machine. This machine, in short, is required in order to cut the blanks to correct size.

One method of producing part A2 would be to pass it over a planing machine on the one side, and again through a planing machine in order to obtain the desired thickness. These two operations are repeated on the edges, and then again to a given shape on each edge, until the correct section is produced. This will involve quite a number of operations. In fact, if single-operation machines were employed, twenty-two operations would be necessary to produce the part, whereas by adopting special-purpose machines that number can be reduced to seven.

In fig. 6 is shown a diagram which will serve to illustrate the usual method in which an ordinary wood-planing machine operates. The material is fed in by a powerful feed roller with a cutter block carrying two cutters and revolving at about 4,000 r.p.m.

A similar principle is embodied in the design of multi-cutter machines which will cut on all four sides at the same time. Such machines are capable of large outputs, and it is necessary to

have an efficient transport system in order to keep them properly fed with material. Provision has also to be made for the frequent collection of refuse, such as shavings.

Machines of this type will deal with timber at the rate of 200 to 250 lineal feet per minute. The author's experience has been, however, that output is governed not so much by what the makers of the machine state it will accomplish, or what the machine is actually capable of, but by what the operator cares to do.

Another machine which can undertake large quantities of work is the gang chain mortiser. The frame of the machine is not unlike the machine-tool known as the rail gang drill; in place of the drill spindles are cutter chains, and the table feeds the work to the chain. One upward traverse of the bed and down again, and as many as twelve complete mortises

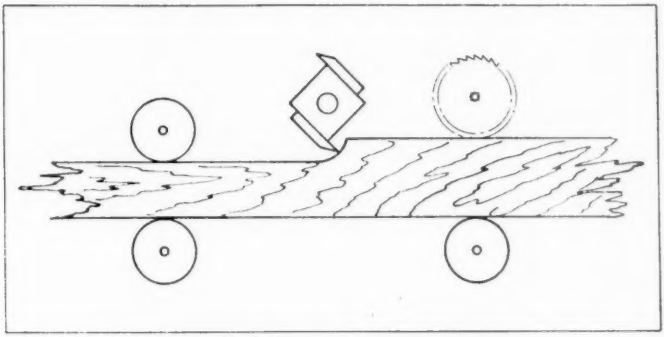


Fig. 6.—Feed rollers and cutter on wood planer.

can be made. It may be explained that the cutter is designed on the lines of an ordinary cycle chain with a cutting tooth in each link, the chain revolving on a sprocket. Various thicknesses of chain are used according to the size of mortise required.

A useful machine in a large bodymaking shop is the double-ended chain-fed tenoning machine. There are two headstocks mounted on a long bed, each headstock carrying two tenoning blocks, both ends of the timber being completed at one operation. The feed is by means of dogs fixed on endless steel chains.

In the case of the machines outlined, they are capable of dealing with straight pieces only. A motor car body, however, is not comprised solely of straight members. Whilst there are many such parts there are others of peculiar contour.

If we look at a plan view of the skeleton of one type of body, it will be seen that the front end of the dash of the body is so small that it conforms to the streamline of the body, yet it

is widened sufficiently at the rear to accommodate three persons. It will also be observed that at the top, or elbow line, it is considerably wider than the bottom portion of the body which is located within the wheelbase, and that this peculiar shape or streamlining throws a large number of the parts into a peculiar

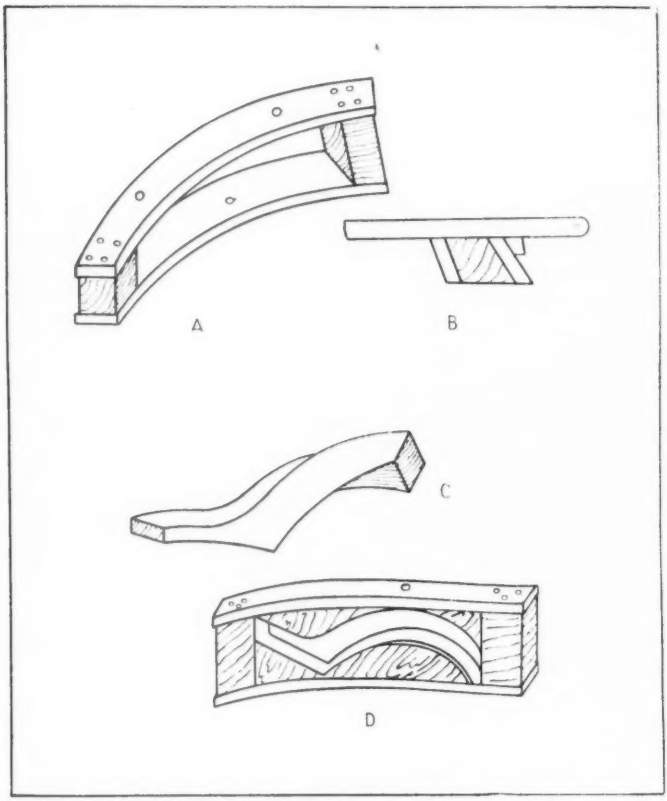


Fig. 7.—An example of the employment of jigs for making parts of special contour.

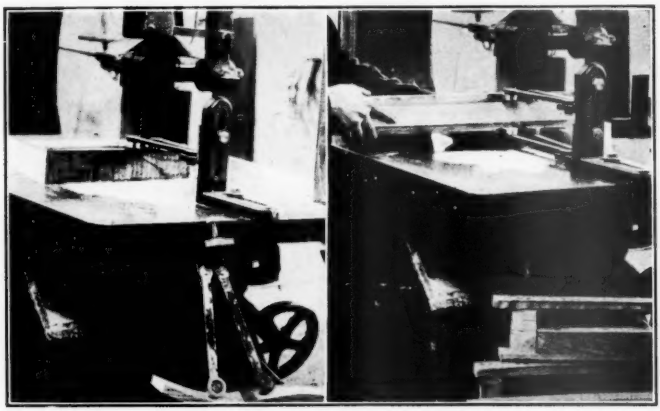
twist. It is these particular members which require different treatment from the straight pieces.

One method of manufacturing peculiarly shaped pieces is to make suitable jigs which in reality are negatives copied from the original positives.

Referring to the illustration in fig. 7, the original piece marked

C has attached to it pieces which are shaped to conform to a straight line in a horizontal or vertical plane as indicated at B. A jig of the form shown at A would produce a blank representative of two of the sides required, whilst a second jig, shown at D, would produce the other sides.

In operation, it is necessary first to cut off a blank and plane to thickness. Formerly it was customary to shape a templet, and then, by means of a pencil, mark the desired shape on the face of the wood. The shape would be cut by means of a band sawing machine, much depending on the skill of the operator. For simple shapes, however, a quicker and more efficient method of production is to fix a couple of pins through a templet, press



Figs. 8 & 9.—Detail of band saw showing special pins and guide rollers on table.

these firmly on the blank, and then, by means of the rig shown in the illustration in fig. 8, follow the outline of the templet, pressing against the guide rollers, something after the manner of a profiling machine. This procedure is well suited for pieces simply cut square off, and where there are no twists or bevels.

Where such shapes have to be cut, the blank is secured between two sides of a jig, as illustrated in fig. 9, and although it may be square at one end, it diminishes or twists to a decided bevel at the other end. By pressing each edge of what may be termed a double templet against the four guide rollers and passing these through a band saw, the result will be the production of a piece of the correct contour and bevels without any marking out. The finish left by the band saw may not be sufficiently good, and it may be necessary to put a smooth surface on the work, or to

reduce the size of the piece to within finer limits than is possible on a band saw.

The same jig may be used on the vertical spindle moulding machine, using straight cutters suitably mounted on collars, the distance between the collars being the same as that between the sides of the jig.

Whilst the methods described are effective—some thousands of copies have been made—and the jigs simple, for intensive production machines have been designed capable of dealing with the complicated shapes necessary to produce a motor car body. In fig. 10 is illustrated a machine which was originally designed

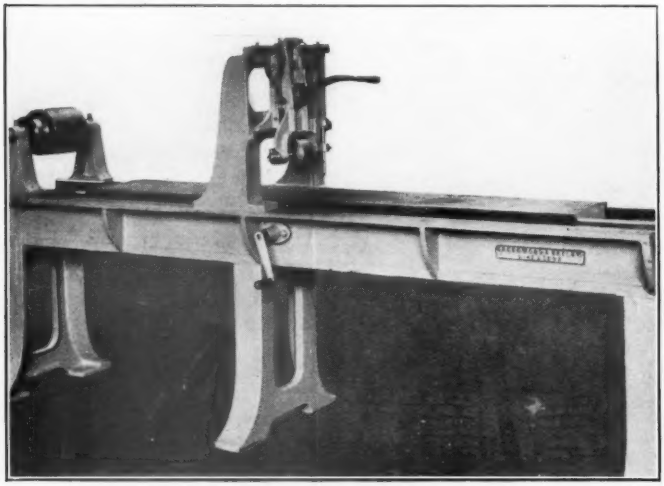


Fig. 10.—Machine originally designed for gun-stocks now producing motor car body parts.

for the manufacture of gun-stocks, but has proved an exceedingly useful machine for motor car body parts. The blank is clamped on to the bed, which traverses the full length of the machine, whilst a floating horizontal cutter block follows, by means of a copying pin, the work to be produced. It has the disadvantage, however, of operating on one side only, and the clamping down of complicated shapes often presents difficulties.

A profiling machine is illustrated in fig. 11, which is fitted with four vertical spindles. Each spindle carries a tool of a different kind, the copy pin for each tool being also of varying shape in order to conform to the different parts of the copy. It is not suggested that such a machine will render unnecessary

jigs or fixtures that have to be produced from the original pattern, but such machines can undoubtedly be employed to advantage according to the quantity of bodies to be made.

Some idea of work going through a sawmill in batches may be gathered from the illustration in fig. 12. Truckloads of various parts are in transit from one machine to another, the piece which

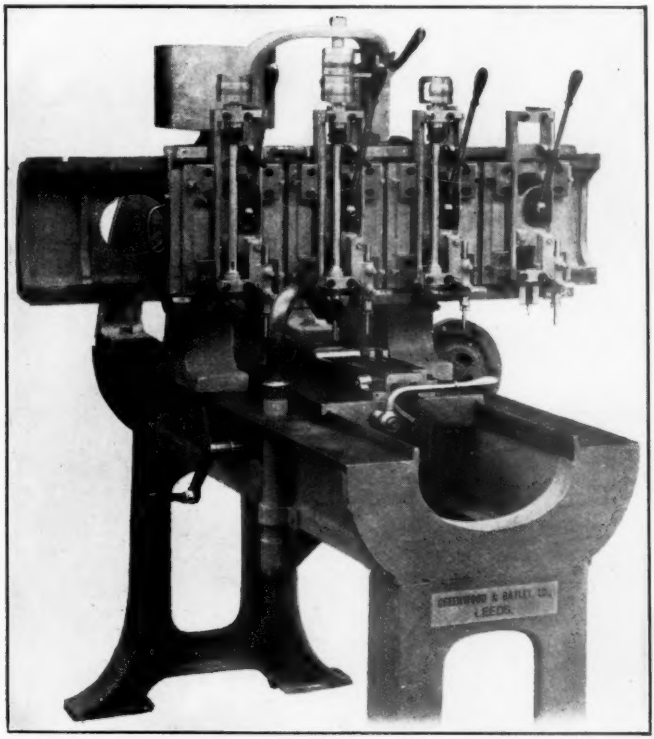


Fig. 11.—A four-spindle copying machine.

has been designated A2 being very prominent in the central foreground of the view.

Jigs can be advantageously employed in the assembling of the various parts into components just as they can in the shaping of them, and in the illustration shown in fig. 13 is to be seen a truckload of door-frames assembled on a jig. The rig for door-frames is simply a table with a series of locating blocks,

Fig. 12.—Batches of work in transit.

Fig. 13.—Door frames assembled by jig.

the blocks being screwed into position to accommodate the parts. For the sake of simplicity, the numbers of the parts are usually painted on the jig.

For the purposes of assembly by hand, a number of containers or receptacles for screws are often fixed under the rig adjacent to the joint where they have to be used. An automatic screw-driver can be used with such a jig, and where this is done receptacles are, of course, unnecessary.

Not only are jigs used for assembling comparatively small units such as door-frames, but they can be utilised for large work such as complete body-frames. A few skeletons that have been

Fig. 14.—Skeleton bodies assembled by jig.

put together by this means are shown in the illustration in fig. 14.

Needless to say, the design of a body affects materially the question of production. For example, whilst some bodies are so designed that every panel used has to be beaten to shape, others are so constructed that an equally effective contour can be obtained by simply passing the sheets through bending rolls.

In the illustration given in fig. 15 is shown a partial view of 700 motor car bodies that have been produced in the manner described. In fact, these are the actual bodies as used on the car typified by the illustration in fig. 1. There are only two pressed panels on each body, the remainder having been rolled.

Even intensive and efficient production can occasionally break

down, and it cannot be claimed that 700 bodies all stored in one place instead of being on the move is efficient organisation. An accident was responsible for the holding-up of this large quantity of bodies, but, as the accumulation was used up in a few days, the interruption was not serious.

There are other interesting processes connected with the manufacture of bodies, apart from the construction of the details. There is the question of painting, and whilst this process does not legitimately come within the scope of these notes, reference may be made to the system of applying paint by the "flowing gravity" principle. Fig. 16 shows an operator at work.

The system comprises a tank containing paint or varnish, placed

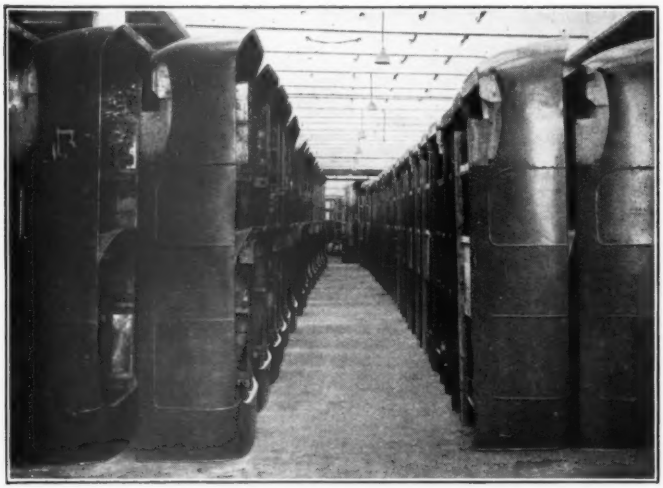


Fig. 15.—Partial view of store of 700 bodies.

sufficiently high to enable the paint to be fed by gravity through a tube to a nozzle which sprays it on to the body. The surplus paint drains off into a tank below, to be pumped up again to the tank. A sieve catches any sediment that may have been introduced in the circulation.

After passing through the drying room, the bodies are ready for the trimming and finishing operations. The illustration given in fig. 17 shows a large batch of bodies which are passing through the trimming shop by means of three conveyors. The first operation is performed as the body arrives from the paint shop, and then is pushed forward ready for the next operation, and so on until the whole of the trimmings have been fixed in position.

The final series of operations is the mounting of the hood and screen, the bodies being then ready for fitting on the chassis.

A few words of explanation as to the working of the conveyor may be of interest, the one to be described being of a very simple nature. As will be seen from the sketch reproduced in fig. 18, the construction is simply two pieces of timber on their edges

Fig. 16.—Paint-spraying motor car body.

braced together to form, as it were, a permanent track. On top of these two pieces are screwed some hard wood caps. These pieces were designed to be replaced if wear should take place, but they will last for very many years. A slipper of simple design fits on the hard wood caps, the bodies being mounted on two of the slippers. By such means the operator pushes the body forward after the completion of an operation.

In adopting the conveyor system, the problem of timing the operations so as to obtain a steady flow of work has to be solved. The author evolved a scheme based on the following lines.

If No. 1 operation takes, say, 75 "man minutes," that is, equal to three men with 25 minutes' work, the amount of work required at each of the other stations must be computed and suitably arranged. Thus, if a small operation requires 5 minutes only, and the body is to remain at that station 25 minutes, it is necessary to group at that point two or three jobs equal to 25 minutes for one operator. If, on the other hand, the work at that particular station takes 50 minutes, that point in the schedule is equivalent to two stations of 25 minutes each.

Fig. 17.—Motor car bodies in trimming room.

Suitable rigs can often be devised for the preparation of the trimmings for fixing to the body. An ordinary type of wood band saw can be readily adapted for cutting cloth, a band knife being substituted for the band saw. Layers of fabric are placed on top of one another, the shape being marked out with a piece of French chalk on the uppermost piece. The whole is then passed under the machine, with the result that thirty pieces can be cut at one operation, an obviously much speedier process than cutting one shape at a time by a pair of scissors. After the pieces of cloth have been cut, or it may be leather, or leather substitute, they proceed to the sewing machines. The next operation is the pressing into shape by means of moulds the cushions, or rear of side squabs—that is, the filling of them with hair to

the desired thickness. Hand presses, and frequently hydraulic presses, are used for this work.

As to the method of making the moulds, in the first place a piece of wood is shaped to the outline of the cushion on the surface. At each point where it is necessary to insert a button, a clip to hold the button is screwed into position. A series of buttons is thus inserted in the clips. The leather is next laid on, and a box placed around it. The box is filled with hair and then covered with canvas. The top mould is then placed in posi-

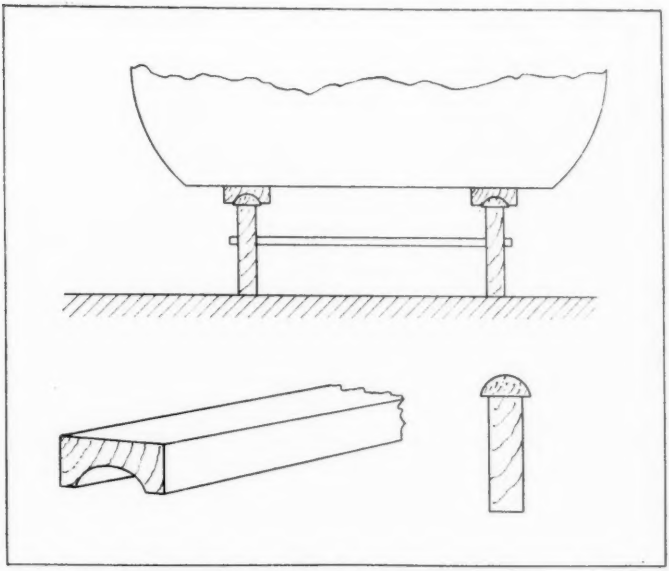


Fig. 18.—Track with slipper blocks for moving motor car bodies.

tion under the press, and pressed until the prongs of the buttons penetrate. In order to give sufficient clearance for the button, a temporary cap with a clip attached is placed over the button and taken out after the hair has been pressed. The prongs of the buttons are then bent over fibre washers, thus holding the hair in position until it is finally tacked into the body.

The methods described, although they have been illustrated by taking the manufacture of a simple type of body, are, nevertheless, not restricted to simple types—bodies of a more complicated character can, with equally efficient results, be produced.

These notes must of necessity cover the subject in a general way. If the author had dealt with the detail of the subject, several papers would have been required to cover the many points.

THE DISCUSSION.

THE PRESIDENT said that he had listened with great interest to Mr. Eastwood's paper. At one time he had been engaged in constructing bodies in what were then considered large quantities—twenty or thirty of a type in a week, and perhaps 500 to 700 of a type in a season—and similar methods were then employed for shaping the woodwork. One great difference he had noticed in modern body construction was that mortise joints seemed to have disappeared altogether, and had been replaced by butt or halved joints. He would like to receive the observations of bodybuilders on that point, because, formerly, one would not have got a good coachbuilder to make such a joint as the butt. Also, so far as he could see, there was very little bent wood used in the construction of the bodies described in the paper. He had employed bent English ash very extensively to great advantage, especially in the building of the large closed bodies. The door frames of landaulettes and limousines were formed of bent ash; the rear pillar was carried round and bent into the sill, instead of being jointed in two places. This made a stronger and lighter construction and cut into less timber. Another point which had a large bearing on the economy of bodybuilding, which Mr. Eastwood had not touched upon, was the initial breaking up of the timber. It had always been a source of much admiration to him to see a good sawyer work up a tree or plank into a number of useful pieces without making too much firewood. Mr. Eastwood had suggested that by using certain devices it was not necessary to mark the timber before cutting to shape. It would appear to him (the President) that it would be impossible to break up a plank to the best advantage unless it were marked out beforehand. Another interesting problem was that of the seasoning of timber. There was much difference of opinion at one time as to whether kiln-dried timber was good to use or not, and how long it ought to be seasoned.

MR. HAMLIN HAMSHAW (Institute of British Carriage & Automobile Manufacturers, 16a, Soho Square, London, W.1), dealing with mass production, said that nobody in this country had ever carried out anything like mass production in the same way as it was being carried out in America. Here it was more of a batch production, and if there were twenty-five bodies at a time to construct it was thought to be a good order. He believed this country had got back to individualism again, and the belief was general in the coach trade that mass production could never attain very great proportions in Great Britain. It was all very well in America, with its big foreign trade in low-priced cars, but in this country one had to deal with people who did not care about having numbers of bodies all of one design. The Britisher always liked to have something different from other people, and mass production

involved sameness. If a firm were concentrating on mass production, it could not take an order from a man who wanted any changes made. It was felt that at the present time the safety of the whole business lay really in individualism rather than in quantity production. He did not believe that any of the large motor firms would be able to continue on anything like a mass production basis, because British taste was different from American. With regard to the artificial seasoning of timber, it had been repeatedly proved that artificial seasoning was practically as good as the old time seasoning of timber. Experts had proved during the war that artificial seasoning, carried out properly, would give results as good as if the timber were seasoned by old-fashioned methods. Mr. Eastwood had referred to the flow-on system of painting, which was used by a good many firms, but only one colour could be painted by that system, which was a handicap in painting in quantity production. A man did not like a motor car all one colour, and no two men liked their cars painted alike. He had learned one or two points from Mr. Eastwood, and hoped that at some future time he would extend his paper and deal with specific problems. The greatest help that could be given to the trade would be to teach the smaller factories how to manufacture their goods cheaper than they were able to do at present.

Mr. E. J. H. Lemon (Works Manager, Carriage & Waggon Dept., Midland Railway, Derby) said that the older a trade was the more difficult it became to get those connected with that trade out of the groove; and, as the author had observed, the trade of coach bodymaking dated back into the remote ages.

In the machining operations in sawmills, or in woodworking machine shops, there was just as much room for the application of manufacturing methods as in an ordinary metal-working machine shop.

The present practice was, in a good many cases, for example, in making tenon and mortise joints, for the mortise to be made first, and the tenon to be made to fit it; and there were few cases where the tenons and mortises were interchangeable.

In order, however, to get interchangeability in a woodworking machine shop, the first thing that requires to be done is to see that all the tools and cutters are made within certain fixed limits—say, two-thousandths over or under.

The next thing to do was to install a proper system of gauges, and to insist on the good machinemen working to within such gauges. To show the necessity, for example, of standardising tools such as square mortising chisels: it had been found that these tools varied up to as much as $\frac{15}{1000}$in. It was, of course, quite impossible to get accurate interchangeability unless, as already pointed out, the tools were first standardised.

Having standardised the tools, the next step was to try standardising the limits to within which (to stick to the example cited) all mortises and tenons should be made. After a few experiments carried out in the shops with which the speaker is associated, the conclusion was come to that, in order to ensure interchangeability, and to allow for a slight variation of $\frac{2}{1000}$in. over or under on the tools, it was necessary to make, say, $\frac{1}{2}$in. mortises $\frac{4}{1000}$in. smaller than the tenons in order to attain a good fit.

Another point arose in connection with tenons and mortises.

Anyone who had watched coachbuilders assembling a body would have noticed that the tenon was first tried in the mortise, and then taken out and eased slightly on the corners, in order to give it a lead, and to see whether the member was home on the shoulder before the tenon was home at the bottom of the mortise. Here, again, in order to obtain quick assembly, a certain clearance must be decided upon between the bottom of the mortise hole and the end of the tenon, so that, when the member came to be assembled in its place in the body, there was no question of its having first to be tried in, to see whether it was home on the end of the tenon before being home on the shoulder.

In the opinion of the speaker, there was room for a great deal of applied engineering production methods in modern wood-working plants.

Mr. Eastwood touched briefly on the modern four-cutter planing machine with a feed of 200ft. per minute, and he mentioned the difficulty of transport and handling in respect of machines working at such feeds. The speaker had found that the best way of remedying this was to install conveyors to take the timber from the unloading point straight to the machine, and to equip the machine with a self-feeding table. It is impossible for one man to feed a machine working at 200ft. per minute.

Having brought the material to the machine, the next difficulty is in handling it as it comes away from the machine, and to do this it is necessary to devise some means of quickly cross-cutting it (if it needs cross-cutting). Experience has taught that, in order to do this efficiently, it is necessary to divide the stream of the material at the out-feeding end of the machine, so that two gangs can handle it.

With regard to the gang chain mortising machine, he asked the author's opinion as to whether that type of machine was very successful on repetition work. He also asked to what extent the author used jigs for assembling purposes; and what was his opinion on the question of sub-dividing the assembly, in order to get quicker construction.

Mr. Bonallack (Messrs. Bonallack & Sons, engineers and body-builders, London, E.1) expressed the appreciation of the Institute of Carriage Builders for the courtesy of the Institution of Production Engineers in extending to them the invitation to attend the meeting. There were two practical points he would like to emphasise. One was the use of circular cutter blocks. Each of the machines shown on the screen was fitted with an old-fashioned square type block, with an ordinary plain cutter mounted on two square surfaces. It was almost impossible, with a cutter of that type, to work to an elaborate jig and produce a satisfactory result, and he had found that by the use of circular cutter blocks, with vertical spindles, satisfactory results were obtained. There was, however, some difficulty in getting them, as circular blocks were not made in suitable short lengths until recently. Another point was that if one were going to work on a spindle it must be on a double-headed machine, with right and left-handed cutters. One would then proceed as far as possible with the grain with the right-handed cutter, twist the jig round in order to use the left-hand cutter on the other side of the table, and go back again if necessary. That method was rather slow, but produced an emi-

nently satisfactory result. With regard to extensive stores of finished parts awaiting assembly, when looking at those projected on the screen he had wondered how the firm had succeeded in avoiding sufficient distortion to make them unusable when they ultimately came to be assembled. Some friends of his in the industry a little time ago had accumulated a large quantity of parts, which it was hoped would ultimately be turned into cheap bodies at a profit. When the time came to assemble those parts, however, a few bodies of a kind were made, but the larger part of the material was burnt.

THE PRESIDENT stated that he was very interested in what Mr. Lemon had remarked about limit gauges, and said others had met with that difficulty. To overcome that he had had to make male and female gauges, which all tenons and mortises had to pass. Then those were dispensed with by not using tenons and mortises, so that one advanced in that way. With regard to mass or batch production, he did not agree with what had been voiced with regard to the impossibility of building things alike and finding a sufficient market. Everybody desired, of course, to have beautiful shapes and nice colours, but the vast majority of people were satisfied to repeat what they could see looked pretty, and if the coachbuilders could produce a beautifully-shaped, nicely-finished and nicely-painted pattern, he was quite certain it would sell in large quantities. What they wanted to discuss was how to accomplish that, and how to get on and turn them out in thousands instead of twenty-fives.

MR. ROPER referred to painting, and the view which had been projected on the screen illustrating the use of the flow-on system. He asked whether it was the general practice in Messrs. Arrol-Johnston's factory to use the flow-on process for painting and for varnishing. For instance, when dealing with a body of a light colour, such as cream, did they flow-on the paint and varnish, or spray it, or put it on with a brush?

MR. PATTINSON agreed that it was necessary for the bodybuilder to make up his mind in the first place as to what and how he had to produce, just as the engineer had to make up his mind.

As to the question of working to proper prints, it seemed rather strange to him that coachbuilders worked more or less to lines and yet did not have a correct system of dimensions. If that state of affairs were to obtain generally in the engineering industry he was afraid that disaster would quickly overtake the trade. Possibly Mr. Eastwood did not wish to infer that the lack of fully-dimensioned drawings was the usual thing in the coachbuilding trade. In the works with which the speaker was connected, the print question was a colossal one, as would be realised when it was stated that several thousands per week were in use.

The author stated that parts were liable to become mixed in the stores, and this made it very difficult on mass production methods. He did not see why there should be any confusion if there were a proper system of recording—it was a case for the adoption of the right measures.

In another part of the paper the author said that there were two or three methods of allocating the work to certain departments. One method was that of sending the work to particular workmen by name; another, that of forwarding it to a workman's shop number; and the third was that of sending it to a machine number. The bodybuilders might, with advantage, take a page out

of the engineers' copybook, as he believed the machine allocation number was the best method.

In connection with the building of dashboards, which was a similar type of work to that in which Mr. Eastwood was engaged, he (the speaker) had found that by the use of a trunnion jig it had been possible to reduce the time limit of each dashboard to about one-third the original time by simply revolving the jig in each progressive stage of manufacture.

Paint spraying was not new to him because in the works with which he was associated the chassis were paint sprayed, and he should imagine that in Mr. Eastwood's case the paint-spraying method was used more or less to give the body a sort of foundation.

With regard to one of the speaker's remarks on mass production, he considered that it was a fallacy to assert that such methods were not practicable in Great Britain. It had been stated that mass production methods were quite suitable for America, but that in this country many customers required their car bodies built to their own designs with the object of possessing something different from other people. Such cases appeared to him to be in the minority, and why should not the working man have his car and the manufacturers build on a quantity production basis? If, as asserted, the Britisher was given to whims and fads and was content to disturb the whole industry in order that he might be able to secure something different from that which everybody else had, and so allow foreign countries to invade our markets thanks to mass production methods, then it was time an attempt was made to educate the people who were buying.

We appeared to have sunk into a lethargic state, and he still felt that when we spoke of mass production in this country, it was as if we were speaking of something impracticable. He would point out to those critics of quantity production methods and its products that the very buttons of their jackets were the result of mass production manufacturing. He did not see why mass production methods were more possible in America than here.

He felt that if bodybuilders would make a tour round some of the engineering shops and see some of the very complicated pieces that had to be machined, they would learn something very useful. It appeared to him that bodybuilders should introduce more jigging methods and take steps to develop an efficient mass production system. He should imagine there was really great scope in the bodybuilding trade for engineers who would make a special study of its problems and products. There would seem to be a greater field for the installation of automatics with special cams, and so on.

Mr. Osborne said that, speaking as a coachbuilder, and one dealing with London customers, their one great idea seemed to be the securing of originality in spending their money. The greater portion of the gentry in this country would not favour the products of quantity manufacturing methods, so far as bodies were concerned. Such products, as he had seen them, were very blatant. The gentleman owning a motor car wished in many cases to possess a more or less distinguished car—away from the ruck. Those users of automobiles never would have it in the old days, and he felt convinced they would not conform to the wishes of the mass producer in these days. His opinion was that the ingrained desire

for originality in shape, design, finish, and so forth, would always assert itself in this country.

Mr. Jacobs pointed out that Mr. Eastwood had said that in producing a motor car, it had to be turned out at a given price. In the initial stages the major portion of the allotted money was spent on the chassis, and if there were any left it went to the making of the body. Therefore, mass production methods must be adopted in order to turn out the bodies within the price. Bodybuilders, however, could not adopt mass production methods unless engineers turned out a standard chassis, because the dimensions of no two chassis were alike in any one point. It was impracticable for a bodybuilder to be a mass producer, because chassis makers would not standardise among themselves. With regard to providing limits, he pointed out that one piece of timber would vary from another so much that it would throw out any limit. Certainly, if left for any considerable time, it would shrink or otherwise vary. Steel was quite different in its properties from timber. Mr. Eastwood had mentioned the rusting of the panels beneath the paint. In this connection, Mr. Jacobs said that the firm with which he was connected had had to resort to the use of aluminium exclusively. He did not know the reason why panels rusted, but another Institution had been trying to find a suitable steel for use in making panels and wings, but so far without success.

A Speaker, dealing with the subject of painting, said there was a firm in the Manchester area which had all its bodies passed through a spraying tunnel. The paint was sprayed on to the bodies in one part of the tunnel, and the body was taken to another part of the tunnel, which was heated, a specially quick-drying paint being used. He did not know, however, how long that method had been installed, nor whether it had been entirely successful.

Mr. Eastwood, replying to the discussion, stated that if the speakers would read his paper again they would find that they had all substantiated the statements made in it. Owing to the shortness of time he could only deal with the queries raised in a general way.

During the war several of his colleagues in the coachbuilding trade, including Mr. Hamshaw and himself, had spent a whole evening considering the problem of the artificial drying of timber, and on the present occasion Mr. Hamshaw had said that he believed timber could be artificially dried with results equal to those obtained by the old methods of drying. However, it was a most difficult matter to introduce such innovations into the coachbuilding trade. In all probability the cause lay in the archaic methods that had been instilled into coachbuilders for generation after generation. His father, grandfather, and great-grandfather were coachbuilders, and the trade was hoary with tradition.

The question seemed to have resolved itself into one of whether to adopt mass production methods or to adhere to individuality. It was possible to have both. If, as had been pointed out by one speaker, the gentry of this country would not purchase the products of quantity production methods, then it must be borne in mind that we were not all gentry. If the motor engineer had not adopted the most efficient methods in the production of the chassis, there would be fewer motorists than there are to-day. There were some bodies on the road to-day that had cost considerably more than the

chassis beneath them, and that would probably always be the case. If it were right, however, for so many persons to stipulate just what colours, sizes, and shapes they required for their car bodies, then why should not chassis be built on the same lines? Where were the gentry who required chassis built to their requirements, with special gears, and even tyres?

He was not concerned with the production of one type of body, neither was he concerned with putting bodies on one type of chassis. When the firm with which he was connected adopted methods by which bodies could be manufactured in reasonable quantities, so large an amount of work was executed in so short a time that they had to absorb the output of chassis from two other factories in order to keep the department at work.

Mr. Lemon had struck a comparison between machine shop practice and sawmill practice and the adoption of gauges. He agreed in the main with Mr. Lemon's observations, and he (the author) was nearly always with the engineer on the question of mass production, and he confessed he had learned a great deal from engineers. There was still more to be learned by the coachbuilder from the engineer, but time would show whether the use of gauges would become widespread. Gauges could be used, and were used, but when an engineer's male or female gauge was spoken of with a plus or minus of a few thousandths and consideration given to its application to timber, it must be remembered that certain modifications had to be made to adapt such gauges to meet the needs of coachbuilders.

It might be found possible or essential to work in thousandths on one piece of timber, but with the next piece considerable tolerance would have to be allowed to deal with the material coming from the stores.

It was all very well to talk of thousandths to an engineer, but it was a different matter to discuss thousandths with a coachbuilder. If sixteenths, thirty-seconds, or eighths were spoken of, the coachbuilder was quite familiar with those dimensions, but not with thousandths.

As to the point raised regarding the place of the gang mortiser to-day in the coachbuilding industry, this machine was certainly an innovation. At present there were certain limitations in its use, although the day of the gang mortiser would come, but he did not think the chains had reached that state of perfection on which they could really be relied. He was still using a single chain machine, and he believed better and quicker results were obtained than with the gang mortiser. There were some uses to which it could be put with advantage, and he should think the machine could be utilised with satisfactory results in railway carriage work when using fairly soft wood.

MR. LEMON here stated that he had found the gang mortiser successful on very hard walnut.

MR. EASTWOOD replied that with a chain mortiser success depended to a large extent on the feel of the chains cutting the wood. It was naturally a difficult matter to depend on the feel of a dozen chains working simultaneously.

As to assembling by jigs, whilst he would not care to be positive on the point, he believed he could assemble a railway carriage on this method. In 1913 he invented a device which he believed would

enable a railway carriage to be readily assembled. It was on the jig principle. It was not so much a machine for putting bodies together as one which would make construction on the jig principle easier.

Mr. Bonallack had referred to the type of cutters employed on the vertical spindle machine. The view projected on the screen certainly showed an antiquated cutter block, but the principal object was to illustrate the double type of jig. With this jig pressing top and bottom on the two guides it was not essential, as in many cases, to have two cutters revolving in opposite directions, because with a straight-faced cutter it was quite easy to cut up to a particular part, and then turn the material over and out in the same direction.

Mr. Roper had referred to the flow-on method of applying paint. Every coat of varnish on the bodies shown on his firm's stand at the Olympia Show in 1921 had been applied by that method.

With price an important factor, and competition a very serious thing, and bearing in mind that sooner or later we should be competing with other countries for our very existence, it was necessary to look ahead.

Dealing with the question of competition, some people might be tempted to question his wisdom in coming there to explain how to surmount the difficulties with which others in the trade were confronted. Competition was not, however, confined to our own land, and, therefore, it was necessary that coachbuilders should help one another. He was willing to talk of his own experience, and if he were allowed to visit other coachbuilding factories in the country and thus gain information he would be exceedingly grateful for any such opportunities.

THE
INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting was held at the Institution of Mechanical Engineers, London, on Friday, March 24th, 1922, the President, Mr. Max R. Lawrence, being in the chair.

The minutes of the previous meeting were read and approved.

Mr. E. Fairbrother then presented his paper on the subject of "Inspection Methods."

In the discussion which followed, a number of the 71 Members and visitors present took part.

At the close of the Meeting the President announced that before the next General Meeting took place Members would be invited by the Secretary to nominate candidates for election on the Council. He mentioned that the existing Council, being the first, was to a certain extent self-elected, but, bearing in mind the good work they had accomplished on behalf of the Institution, he hoped that no radical changes would take place.

Whilst the Institution was authorised, according to its rules, to carry a maximum Council consisting of 22 ordinary members, together with Vice-Presidents, etc., the President thought that at the present stage it was inadvisable for this number to be elected. Further he considered that it was more advisable to err on the small side, thus leaving a number of vacancies that might be filled by co-option when suitable persons were persuaded to take an active interest in the work of the Institution.

Votes of thanks to Mr. Fairbrother for his paper, and to the Institution of Mechanical Engineers for the loan of the hall, concluded the proceedings.

It was announced that the next General Meeting would be held on Friday, April 21st, at 7.30 p.m., when Mr. J. R. Smith, of Messrs. J. & E. Hall, Ltd., Dartford, would deliver his paper dealing with "Electricity in the Modern Engineering Works."

INSPECTION METHODS.

By Mr. E. FAIRBROTHER, A.M.I.A.E., A.Fe.A.S., Engineering Manager of Messrs. F. W. Berwick & Co., Ltd., Park Royal, London, N.W.10.

Introduction.

The author realises the controversial nature of this subject, and proposes to deal only in a general way with the development and practice of inspection.

The development of inspection in many of its aspects has followed, as a natural sequence, on the adoption of intensive and specialised methods of manufacture.

It must also be freely admitted that Government inspection during the late war has had a marked effect on the inspection methods of a large number of manufacturers.

In spite of the adverse criticism of official inspection—often made without justification—it cannot be disputed that interchangeability reached a very high degree of perfection, and the author ventures to say higher than that reached in commercial practice prior to 1914.

During the war the author had a unique opportunity of closely studying the facilities provided by a large number of manufacturers for the inspection of parts and the finally finished article.

It was very interesting to observe how slowly but surely manufacturers of large complicated mechanism like aeroplane engines began to realise the advantages of inspection of both finished parts and raw material.

It is difficult to imagine the disheartening effect on a works manager and his subordinates when making superhuman efforts to produce parts in accordance with a programme of production, to find that a big batch of parts has been scrapped in the hardening shop, because incorrect material has been used; or that a large number of finished parts ought to have been scrapped during the first operation, but, owing to defective workmanship due to lack of efficient inspection, a lot of unnecessary work had been performed.

Is Inspection Necessary?

The question is very often asked—Is inspection necessary? The reasons for inspection may be given under several headings:

(a) To avoid scrap.
(b) To assist semi-skilled labour engaged on repetition work.
(c) To relieve the foremen and works manager of routine work.
(d) To safeguard the designer.
(e) To facilitate erection.

(a) *To avoid scrap.*—It is obvious that a great waste of labour may be avoided by stopping any further work on parts which are defective or scrapped during an early operation. Castings or stampings in the raw state may be defective, and, as such, should not be issued to the shops. The only economical way of obviating such trouble is by inspection. The alternative to inspection is that the operator must examine each part before commencing any operation, which in a large factory entails a considerable loss of machine hours.

It is appreciated that the castings, stampings, and the like, may have hidden flaws which can only be detected as and when revealed by some machining operation. Such parts should be thrown out by the inspection department, thus preventing any further labour being spent on scrap parts.

(b) *To assist semi-skilled labour engaged on repetition work.*—It is now generally realised that the keen international competition prevailing at the present time is a real menace to British industry. In order to compete successfully with foreign countries, it is necessary to reduce our quotations to the lowest amount. To do this, it is also necessary in some industries to resort to the employment of semi-skilled labour. Such labour is always assisted by the use of special jigs and tools or single-purpose machines. These auxiliary devices are subject to wear and mal-treatment, and it is the inspector's duty to prevent the continuance in use of defective tools. Careful and systematic inspection will prevent the production of a large amount of scrap.

(c) *To relieve the foremen and works manager of routine work.*—It is of the utmost importance that the foremen should not be turned into what one might term "glorified clerks." The duties of foremen primarily consist of effecting a reduction in costs of production, consistent with quality. The foreman must not try to hide behind the inspector; on the other hand, he looks to the inspector for assistance regarding the quality of his production.

Furthermore, the inspector, and not the foreman, co-ordinates the works with the cost office and planning department. He is responsible for quantity and, with the foreman, for quality. Also the inspector should provide each foreman with a daily list showing the amount of scrap made in each department and the name and number of the operator responsible.

(d) *To safeguard the designer.*—Some department in a works organisation must be responsible for the correct interpretation of the drawing, as representing the designer's requirements, and it is considered that the inspection department should serve this purpose.

(e) *To facilitate erection.*—Considerable time is lost in the fitting and erecting shops by "juggling" with parts that will not fit. Either the fitter has to adopt improvised methods—which incidentally are expensive—to fit such parts, or the defective ones are exchanged, which means further loss of time in going to and from the stores.

Often when the fitter is on piece-work, the defective part, which may be small, is fitted, or, if large, persuaded to go by the injudicious use of a large hammer. In any case the result is obvious.

Duties of an Inspector.

The foregoing remarks may now be collected, amplified, and set out as the duties of an inspector. For our purpose, the following observations apply to what is known as the "chief inspector."

1.—An inspector is the authorised representative of the management, to whom he should be directly responsible.

2. *Specifications.*—It is the duty of an inspector to see that all material supplied to the company is in accordance with the specification as laid down. He must not waive any points in specifications (outside commercial limits) unless authorised to do so. In cases where no specifications or special instructions are available, he must exercise his judgment in the acceptance of material, ensuring in all cases that the material is suitable for the purpose for which it is intended.

3. *Dimensions.*—The inspector should check all sizes, limits, and weights, for conformity to the drawings, specifications, and special instructions.

The inspector should check stampings, castings, and the like, for flaws, wear of dies, machining allowances, faulty cores, casting hardness, etc. In this connection the inspector should use his judgment and not reject material for differences in unimportant dimensions which do not affect the performance of the material in the service for which it is intended.

4. *Workmanship.*—It is impossible to describe always on a drawing the whole of the requirements of many parts. For instance, the precise amount a piston and cylinder is made oval, the roughness of holes, the exact finish, etc. The inspector must, therefore, use his own judgment and exercise discretion without being frivolous. All matters in doubt should be settled in co-operation with the works manager and designer.

5. *Acceptance and rejection.*—The inspector should carefully mark all accepted material using suitable methods. The author knows several cases where perfectly good work has been hopelessly scrapped by the careless use of an inspection stamp. Rejected material should be scrapped as soon as possible.

6. *General.*—An inspector must always bear in mind that he is to help and not obstruct production. His conduct in the performance of his duties must be fair, so as to inspire confidence and to engender the co-operative spirit in the company's employees.

An Inspection Department—Its Location in the Factory.

An inspection department may be paradoxically described as a necessary luxury. Theoretically it should not be necessary, as operators are paid to produce parts in accordance with instructions. Practically it is found necessary for the simple reason that it is impossible to eliminate the human element. Moreover, as already stated, it is necessary to provide a link between the works and the wages department, and here the inspection department serves a useful purpose.

Furthermore, it is usually found that a properly organised inspection department is an economic factor in any works organisation. Over-staffing of this department must be carefully avoided.

The author would like to emphasise that the inclusion of an inspection department in a works organisation does not relieve the works manager and his subordinates of their responsibility. It is of no use lowering the cost of production to the detriment of the quality of the work produced. Therefore there must be the closest co-operation with the inspection department.

It is the author's firm opinion that the work of the inspection

department must not be " side-tracked " in order to save a little time—to increase quantity at the expense of the quality of the product may be disastrous in the long run. The department must have a separate entity so far as the works are concerned. The chief inspector should be directly responsible to the general manager or the managing director.

The location of the inspection department is of importance. It should be conveniently situated in relation to the machine shops, stores, and other allied departments.

Before discussing this point it would probably be wise to mention that there are two distinct systems employed with regard to inspection. There are also several modifications of these two main systems.

The one system may be described as " floor viewing." In this case, inspectors or viewers, as they are commonly called, are situated in convenient parts of the works. The work is inspected as it leaves the machines, in its own particular group.

It is claimed that this system saves a lot of unnecessary transportation of parts, but on the other hand it necessarily involves duplication of equipment and an increase of staff in the progress department.

It may be economically applied where each department is self-contained and manufacturing some special component. For instance, if the factory is sub-divided so that, say, cylinders are made complete in one portion, gear boxes in another, and so on, decentralisation may be successfully adopted.

The other main system may be described as centralised inspection. In this case the view room is situated in a convenient position, and all work after each operation is taken to the view room. All inspection work is carried out in this view room, and the minimum equipment is required. Under this system, exception is made to central viewing in the case of large parts, where transportation is difficult. It is considered that this system can be best applied to most factories, but its adoption depends on so many factors, and it is difficult to lay down any hard and fast rules.

It is the centralised inspection system which the author proposes to outline, and which is considered to be the most economical system for the majority of moderate sized factories.

Where a separate machine shop is installed the work has of necessity to be taken from one group of machines to another, and the passing of work from the works to the view room does not materially affect difficulty in transport.

The situation of the inspection department in relation to the other departments in the factory is of great importance, and what is considered to be a satisfactory arrangement is shown in fig. 1. It will be observed that the view room is conveniently situated with regard to the allied departments, and is positioned with a view to reducing transport.

It is to be clearly seen from the diagram how the work is moved from the machine shop to the stores, and how it is passed through the view room. Work in progress is moved from the machine shop to the inspection department, and thence to the machine shop bond, where it is re-issued to the machine shop for further operations.

With regard to the raw material, it is also clearly shown that material before being placed in the stores passes through another bond, from whence it is released by the inspection department.

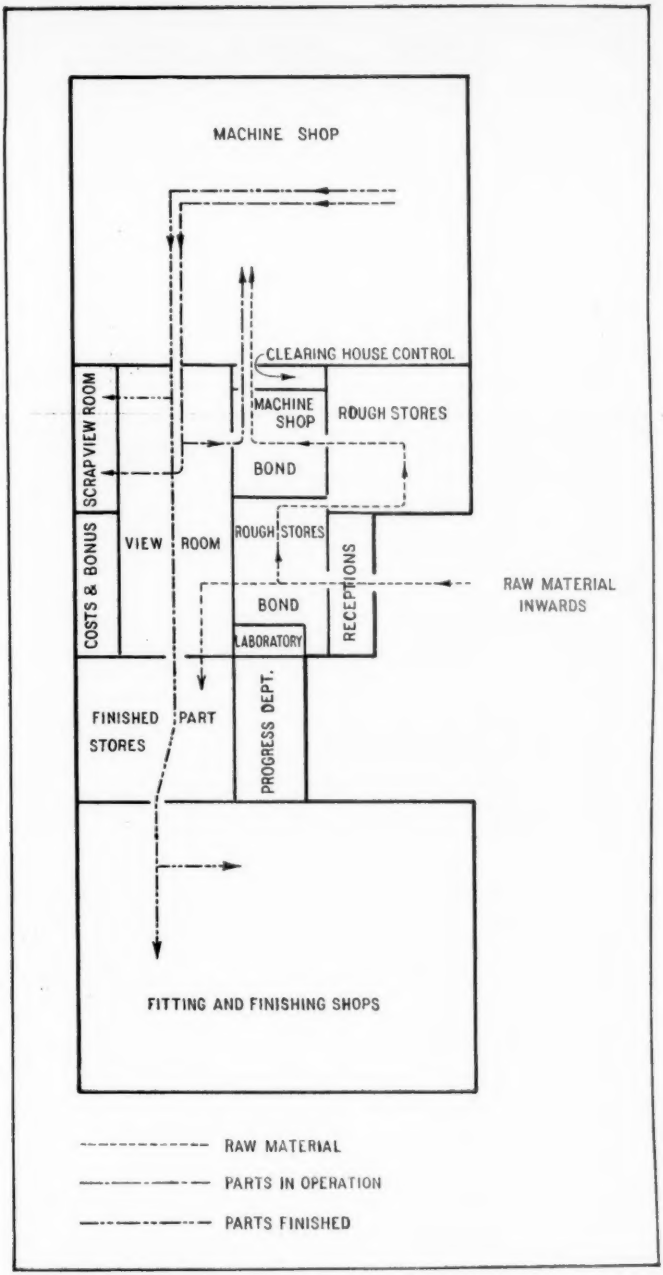


Fig. 1.—A diagram of a shop system with central view rooms.

A System Described.

These notes will have reference to the system where a central view room is employed, similar to that shown in the accompanying diagram in fig. 1. The machine shop in this case is worked on a time piece-work system, and each batch of work is viewed after every operation. A corner of a typical inspection room is illustrated in fig. 2.

It is proposed first to describe how the inspection department is co-ordinated with the various stores, and how the inspection of raw material is carried out before the material is issued to the shops.

All incoming goods are received by the reception department, clearly shown in the diagram, the material is checked for number or quantity, weighed or measured, as the case may be, and signed for as unexamined. After the parts have been checked quantita-

Fig. 2.—A view in an inspection department.

tively, the material is placed in what is designated in the diagram as a rough stores bond, where several viewers are at work examining raw materials and finished parts, depending upon the state in which they are delivered by the firm's contractors.

The finished parts are inspected in accordance with the drawings in the usual way, and if found to be satisfactory are transferred immediately to the finished part stores.

When raw material is received, either in bars, stampings, or castings, analysis cards are made out in the progress department in triplicate, full particulars of the material being obtained from a copy of the reception and order notes. Two copies of this card, a sample of which is shown in fig. 3, are sent to the laboratory, together with a test piece of the material concerned. On receipt of the analysis cards and the test piece in the laboratory, the necessary tests are made, and the results compared with the standard specifica-

tion. At the same time the result of the analysis is recorded on the card, and if the material is found to be satisfactory, the laboratory return one copy of the card to the progress duly signed, retaining

CONSIGNMENT NUMBER 26219

DATE 21.11.18

MATERIAL Nickel Chrome

SPECIFICATION S16 (Pt1) (Pt OS127)

NAME OF MAKER Jonas & Colver

NAME OF SUPPLIER Smethwick Stampings BRAND

QUANTITY 300 Inlet valve Rocker Stampings CONDITION Part 416

ORDER Nº 4929

HEAT TREATMENT SUGGESTED (BY MAKERS)

Cement at 900° for 4 hrs Reheat to 850° Soak for 15 mins in water Reheat 750° Soak 15 mins quench in water

HEAT TREATMENT ADOPTED (BY THE DEPT.)

Nº H.T. 18.

Date _____ Signature H Smith

Reverse side

MECHANICAL TESTS

TESTS	Test Piece Nº	STRESS Yield tons per sq. in.	STRESS Max. tons per sq. in.	ELONGATION %	REDUCTN OF AREA %	BRINELL ON TENSILE	Init'l'd by	TEST PIECE Nº	IMPACT Brinell	IMPACT Foot Pounds	Init'l'd by
Spec'f'n		40	50-70	13-17	30-35					25-30	
1ST						4-6					
2ND											
3RD											

ANALYSES 269

	Carb	Man	Sil	Nick	Chrome	Sulf	Phos
Specification	·½	Suitable	Prop	Max 4·0	1·1	·04	·05
Makers	·16	·48	·21	2·39	·29	040	·039
Firm	·133	·410	·215	1·857	·765	·03	·02

O.K FOR USE OK DATE S. CHEMIST'S SIGNATURE NGC

REMARKS

C

Fig. 3.—An example of a raw material analysis card.

T 2

the other for reference. The return of the analysis card signed by the laboratory authorises the progress to release the material from the bond, and it is placed in the rough material store. In the event of the material being unsatisfactory, the card is clearly marked showing what the specification is and what it should be, and the material is then returned to the supplier for replacement.

A set of heat-treatment cards, an example of which is illustrated

HEAT TREATMENT NUMBER 20

MATERIAL A.B.C. Cams. SPECIFICATION NUMBER S.16

HEAT TREATMENT 20.

PARTICULARS

Carburise at 950 c 6 hours
Refine core 860 c Water
" case 780 c "

Date Signature

SEE OVER FOR CONSIGNMENT NUMBERS

Reverse side

Date	Consignment Number	Date	Consignment Number	Date	Consignment Number	Date	Consignment Number
17.10.18	22426	18.3.19	31392	13.5.19	33721	7.5.19	33382
13.12.18	27446	24.3.19	31639	8.5.19	33522	6.5.19	332720
18.12.18	27721	31.3.19	31938	7.5.19	33380	20.5.19	34016
15.1.19	28759	2.4.19	32030	21.5.19	34070	5.19	34511

Fig. 4.—A heat-treatment and consignment number record card.

in fig. 4, are kept by the heat treatment department, on which is recorded the consignment number of any particular batch of material which has passed a definite heat-treatment. This record is available in case of any subsequent trouble arising.

In no circumstances is material released from the bond until it has been certified as correct by the laboratory.

Should the material come into the factory heat treated, and is of importance, in addition to the analytical tests, mechanical tests

are also carried out, the results of which are also recorded on the card shown in fig. 3.

The laboratory, in addition to carrying out tests and certifying material as being satisfactory and in accordance with specifications, should also enter on the other side of the card the correct heat treatment for any particular material. The heat treatment is slightly modified by variations in analysis in order to obtain the best results from any particular steel. The inspection department know, therefore, exactly what heat treatment is required for every consignment of material received in the factory. When the material is issued to the shops and it is ready for heat treatment, the hardening shop make application for the production heat treatment card, shown in fig. 5, which clearly states all the particulars required in

PRODUCTION HEAT TREATMENT

Part Name Inlet V Rockers — Part No 416
Material Nickel Chrome — Consignment No 32550
Specification S 16 — Shop Order No ABC 243
Name of Maker — Number in batch 100
Brand — 1 Broken A.I.D Test

MECHANICAL TESTS

TESTS	Test Piece No	STRESS Yield tons per sq. in.	STRESS Max tons per sq. in.	ELONGATION %	REDUCTN OF AREA %	BRINELL ON TENSILE	Init'l'd by	TEST PIECE No	IMPACT Brinell	IMPACT Foot Pounds	Init'l'd by
Spec'f'n											
1ST											
2ND											
3RD											

HEAT TREATMENT No HJ 18

Carb 900 °C 5 hr
Refrat 850 °C oil
750 °C oil

DATE 12/5/19 SIGNATURE E Brown

Fig. 5.—A heat-treatment card.

connection with heat treatment, and the physical tests which are to be carried out after the heat treatment has been performed.

After heat treatment a sample of the test piece is again handed to the laboratory for completion of the physical tests, which if found to be satisfactory, are certified as correct by the laboratory, and the material is issued for further operations.

During the time that a sample of the material is being analysed and inspected, the inspection department carry out inspection of the material for dimensions, and a space is provided on the back of the reception note for the inspector's signature, certifying that the material is satisfactory in this respect, and both the analysis card and the reception note must be certified before any material is released.

The material, after passing through these various inspection stages, is deposited in the rough stores, and the bar material is

then cut up according to requirements, and the stampings and castings placed in batches according to the quantities to be issued to the works. They are then sent to the machine shop bond, from whence they are issued by the progress department to the works.

The work is issued in batches (the number of parts in a batch for each operation is predetermined by the planning department, and for the same part the number in a batch need not necessarily be the same for different operations), with a production card, shown in fig. 6, which specifies the quantity in a batch, the material, and the processes.

It is important to note the columns provided on the production card to be filled in by the inspector. The information entered by the inspection department under the respective headings is extremely valuable, and the data supplied are a complete record of what happens to every single part of a batch of work. Moreover, the information compiled is informative, and it is easy to see at a glance whether

PRODUCTION CARD FORM 295

DATE _____ BATCH Nº _____ S.S ORDER Nº _____

QUANTITY IN BATCH [ ] MATERIAL _____

NAME OF PART _____ PART Nº _____

Op. Nº	Man's Nº	M/c Nº	Process	Bonus Reference		Good	Usable	Man's Scrap	M'ker's Scrap	Viewer's Signature
	1			Ticket Nº	Ref.					
	2			Prep.						
	3			B.T.						
	1			Ticket Nº	Ref.					
	2			Prep.						
	3			B.T.						
	1			Ticket Nº	Ref.					
	2			Prep.						
	3			B.T.						
	1			Ticket Nº	Ref.					

Fig. 6.—An example of a batch production card.

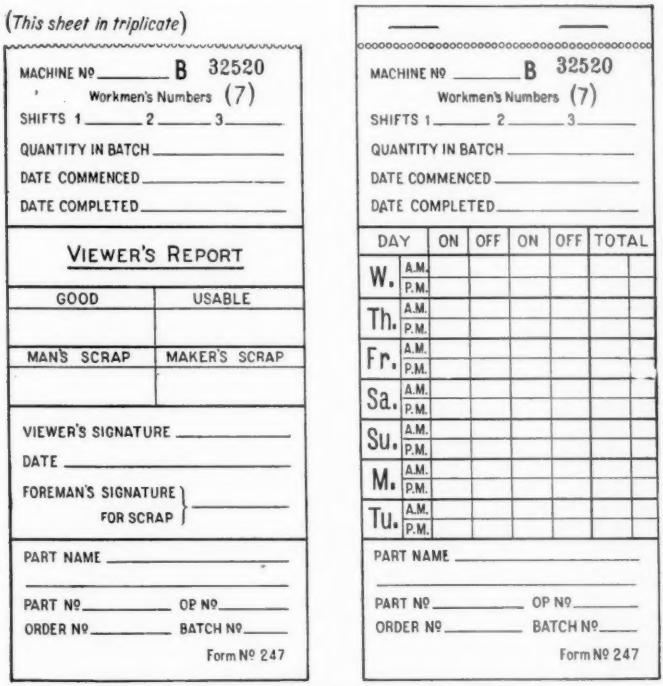
a large amount of scrap is being made on account of defective material, and by studying successive production cards for the same part it is possible to trace at which operation the majority of scrap is being made. This enables the chief inspector to make immediate investigations to find out exactly what is causing the trouble.

The possession of a production card is authority for an operator to commence work on a particular batch of parts. The time of commencement is recorded on a time card in a suitable manner according to the factory system laid down. When the operator completes his portion, the production card is taken by him to the clocking station, and the time of completion is recorded on the time card by the time clerk. Attached to the time card in triplicate are bonus and inspection slips, which are stamped with the same serial number as the time card.

When an operation on a batch of work is completed, these bonus and inspection slips are detached by the time clerk and sent, with

the production card and the work, to the inspection department. The work is inspected and a full report is recorded on these slips, a sample of which is shown in fig. 7, and the slips are then distributed, one copy to the cost and bonus office, one to the progress department, and one to the foreman of the particular department interested. The foreman hands over his copy to the operator, who can see clearly how many parts have been accepted by the inspection department.

The copy which is sent to the cost and bonus office is attached,


(*This sheet in triplicate*)

MACHINE Nº _____ B 32520
Workmen's Numbers (7)
SHIFTS 1 _____ 2 _____ 3 _____
QUANTITY IN BATCH _____
DATE COMMENCED _____
DATE COMPLETED _____

VIEWER'S REPORT

GOOD	USABLE
MAN'S SCRAP	MAKER'S SCRAP

VIEWER'S SIGNATURE _____
DATE _____
FOREMAN'S SIGNATURE FOR SCRAP _____

PART NAME _____
PART Nº _____ OP Nº _____
ORDER Nº _____ BATCH Nº _____
Form Nº 247

MACHINE Nº _____ B 32520
Workmen's Numbers (7)
SHIFTS 1 _____ 2 _____ 3 _____
QUANTITY IN BATCH _____
DATE COMMENCED _____
DATE COMPLETED _____

DAY		ON	OFF	ON	OFF	TOTAL	
W.	A.M.						
	P.M.						
Th.	A.M.						
	P.M.						
Fr.	A.M.						
	P.M.						
Sa.	A.M.						
	P.M.						
Su.	A.M.						
	P.M.						
M.	A.M.						
	P.M.						
Tu.	A.M.						
	P.M.						

PART NAME _____
PART Nº _____ OP Nº _____
ORDER Nº _____ BATCH Nº _____
Form Nº 247

Fig. 7.—Time card with viewer's report slip.

in that department, to the time card which has been previously sent from the clocking station, and the two can easily be traced by the serial number, which is the same.

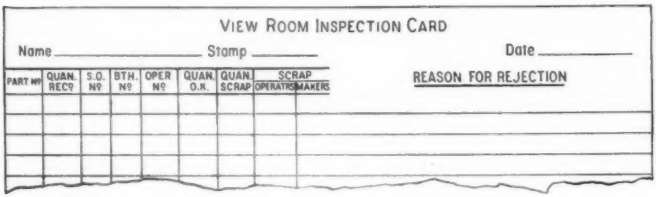
It is quite obvious that the inspection department is serving a very useful purpose in linking up with the work of the cost and bonus department, and no bonus is paid except on the viewer's report. When inspecting the parts the viewer inspects strictly to the drawing, or to any special instructions, and he must either accept or reject parts. No work is allowed to be returned to the operator

for rectification except under special circumstances, and then only by permission of the machine shop superintendent.

This question as to whether work which is capable of rectification should be returned to the operator is a very serious point, and has to be very carefully considered. Anyone who has tried this policy usually finds that the operators gradually develop into producing a very low standard of work, being able to take the risk of spending further time on correction should it be rejected by the inspection department.

All the work rejected by the inspectors is placed in a scrap view room, shown in the diagram in fig. 1. This room is fitted with special bins provided for each department, or each foreman, whichever is the better way, and at the end of the day it may be readily seen which department is making the most scrap.

A form (fig. 8) is provided to record the inspector's daily work. This form contains columns for :– (1) Part number; (2) quantity received by inspector; (3) shop order number; (4) batch number; (5) operation number—obtained from the production card; (6) quantity correct and passed; (7) quantity scrapped; and (8) scrap due (*a*) to operators, or (*b*) to makers.


VIEW ROOM INSPECTION CARD

Name _____ Stamp _____ Date _____

PART NO	QUAN. REC'D	S.O. NO	BTH. NO	OPER NO	QUAN. O.K.	QUAN. SCRAP	SCRAP OPERATOR	SCRAP MAKERS	REASON FOR REJECTION

Fig. 8.—A view-room inspection sheet.

One side of the form is set apart for recording the reasons for the parts being scrapped. At the end of each day these forms are collected and handed over to the chief inspector. Not only do they form useful reference and record valuable information, but they also record the daily work of each inspector, and act as a useful guide for the control of the inspection department.

The inspector should be given as much information as possible, and where circumstances permit, a complete set of inspection data sheets should be provided, drawing attention to any particular dimensions and conveying information not usually shown on the drawings. Such data sheets are illustrated in fig. 9.

Dimensional Inspection.—A considerable portion of an inspector's total time is spent on dimensional inspection; in fact, it is usual to keep inspectors engaged exclusively on this class of work, and to appoint men specially for other work, such as raw material inspection, material testing, etc.

Dealing first with dimensional inspection, it is essential that satisfactory drawings are supplied and sufficient information given to permit of an intelligent interpretation of actual requirements.

Drawings.—Too much care cannot be bestowed on the preparation of accurate drawings, and when the staff in the drawing office are

in doubt on any particular matter directly affecting the works, the chief inspector should be consulted.

The subject of drawings has been admirably dealt with by Guyler

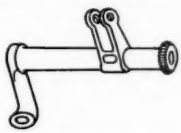
ENGINE _____ TYPE _____

Part and Dwg. Nº _____

VALVE, INLET AND EXHAUST

Nº	Minimum Percentage of Inspection	Directions	Use Gauge Nº
1	100	Snap gauge diameter ·430" ±·0015"	
2	100	Snap gauge diameter ·430" {+·0000" −·0100"	
3	100	Snap gauge diameter ·435" {+·0000" −·0015"	
4	100	Snap gauge diameter ·395" {+·000" −·003"	
5	100	Snap gauge diameter 2·734" ±·003"	
6	100	Profile gauge $\frac{5}{8}$" radius of head and stem.	
7	100	Profile ... 20" ...	

ENGINE _____ TYPE _____



LEVER, CAMSHAFT ROCKER

Part and Dwg. Nº

LEFT HAND. _____

RIGHT HAND _____

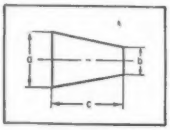
Nº	Minimum Percentage of Inspection	Directions	Use Gauge Nº
1	100	Snap gauge diameter ·624"±·00025"	
2	100	Gauge length 4·1562"±·001"	
3	100	Gauge $\frac{1}{16}$" radius at ends of ·624" diameter	
4	100	Gauge width of arm slot ·383"±·001"	

Fig. 9.—Examples of inspectors' data sheets.

in a complete manner. There is, however, still much more to be done in the standardisation of drawings, and amongst many of the outstanding points may be cited :—

(1) Standard method of indicating limits on drawings; (2) standard way of showing tapers; and (3) standard system of drawing and dimensioning screw threads. The first and third items will be dealt with later.

Regarding tapers on drawings, it is suggested that all tapers should be given on the basis of 1 in $\frac{c}{a-b}$



and as shown on the drawing in fig. 10. The limit should be attached to the small or large diameter, whichever is the more

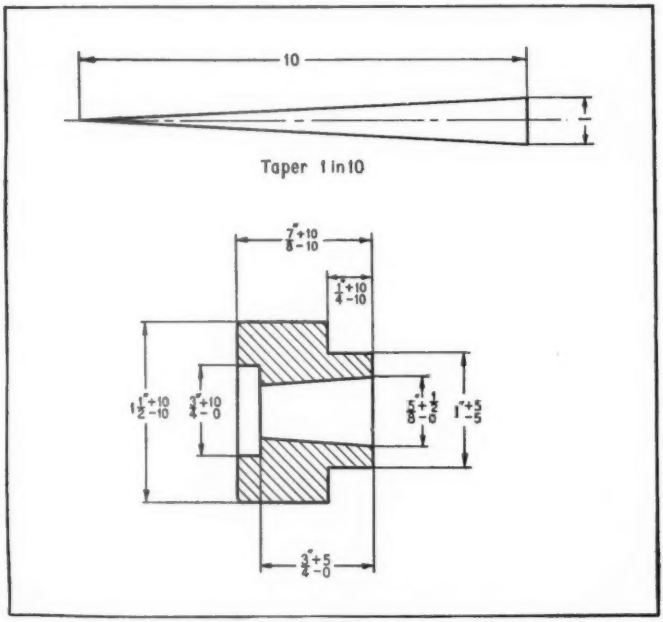


Fig. 10.—A suggested method for showing tapers on drawings.

important. The angle should also be given for guidance in setting up machines.

Limits. (For plain cylindrical work.)—The subject of limits has

been before engineers for the last twenty years, and the fixing of satisfactory limits is the basis of efficient inspection. Without such limits it is impossible to standardise the quality of production and to attain any degree of satisfactory interchangeability.

It is most convenient to state here standard definitions which are now becoming well known and universally adopted, viz., tolerance, allowance, clearance, and limits. For the sake of clearness the terms are explained as follows:—

Tolerance.—A difference in dimensions prescribed in order to tolerate unavoidable imperfections of workmanship.

Allowance.—A difference in dimensions prescribed in order to allow of various qualities of fit.

Clearance.—A difference in dimensions, or in the shape of the

Firm.	Distribution of Allowance.		If any tolerance stated.
	Running fits.	Force fits.	
A.	Divided.	—	Sometimes.
B.	Hole.	Hole.	Always.
C.	—	—	No.
D.	Hole.	Shaft.	No.
E.	Hole.	Hole.	No.
F.	Shaft.	—	No.
G.	Shaft.	Shaft.	Always.
H.	Divided.	—	Sometimes.
J.	Divided.	—	Sometimes.
K.	Usually hole.	—	No.
L.	Usually hole.	—	No.
M.	Hole.	Shaft.	No.
N.	Divided.	Hole.	Always.

Fig. 11.—A list extracted from a 1905 report on precision measuring methods.

surface, prescribed in order that two surfaces, or parts of surfaces, may be clear of one another.

Limits.—The limits may be considered as the boundary lines of the tolerance.

The allowance may be positive or negative, the positive producing what may be termed a clearance fit, and the negative an interference fit, and between the two a transition fit.

In 1905 the British Engineering Standards Association decided to request some of the leading manufacturers of the country to afford facilities at their works for the accurate measurement of plain cylindrical shafts and holes from 2 to 12in. in diameter.* The table given in fig. 11 is of interest as illustrating the methods adopted at that time by a number of the leading manufacturers.

As the result of this preliminary work, which was very valuable

* See British Engineering Standards Association Report No. 25 on "Errors in Workmanship."

indeed at the time it was carried out, the British Engineering Standards Association subsequently issued in 1906 their report, No. 27, on British Standard Systems of Limit Gauges for Running Fits.

This particular system of limits is based on what is known as the "shaft basis," i.e., the shaft is the element more nearly approaching a true dimension and allowance made on the hole according to the class of fit required.

The B.E.S.A. decided to confine their report to running fits only, divided into three classes of workmanship, viz. :—First class, second class, third class. They did not stipulate the adoption of any one of these classes, but recommended they should be used as best met requirements. The standard tolerances and allowances laid down are shown in fig. 12.

Since the time that this report was originally presented considerable changes have taken place in engineering shops in the methods of manufacture. The class of machinery now employed, particularly hole-grinding machines, has led to a reconsideration of the basis on which limits should be fixed, e.g., shaft or hole basis. It has been found that the "shaft basis" recommended in Report No. 27, referred to above, has not been generally adopted, the chief reasons being that compared with the "hole basis," the "shaft basis" is more costly in gauges and tool equipment. It has been found by several investigators that gauging and tool equipment on a "shaft basis" is approximately 45 per cent. more expensive than a gauging equipment for a "hole basis." Summarising this aspect of the question it is now generally agreed that the hole basis is correct, and all modern systems of limits have been established on this basis.

A limit system.—In general engineering practice, the following classes of fits are usually required :—

Force Driving	} interference.
Keying Push	} transition.
Running—1st class Running—2nd class Running—3rd class	} clearance.

Basis (Hole or Shaft).—A study of the British Engineering Standards Association's Report No. 25 reveals that at that time there were divergent views on the merits of the "hole basis" and the "shaft basis," and Report No. 27, issued subsequently, adopted the "shaft basis."

Albeit, engineering practice has been so modernised and circumstances so changed that the "hole basis" is recognised as the standard basis upon which to construct a limit system.

The system should be such, however, that provision is made for variation of holes in exceptional circumstances where it is inexpedient to vary the shafts.

It should be clearly understood that in the "hole basis" system the tolerance permissible in producing a "standard" hole is due only to errors in workmanship, and the amount of tolerance allowed is governed by the quality of work required.

To obtain any desired class of fit, suitable allowance is made on the shaft.

It is easier in practice to vary the size of shaft than the holes, and as previously stated the cost of wearable tools and gauge equipment for the "hole basis" is considerably less than for the "shaft basis."

Disposition of Hole Tolerance.—Assuming that the "hole basis"

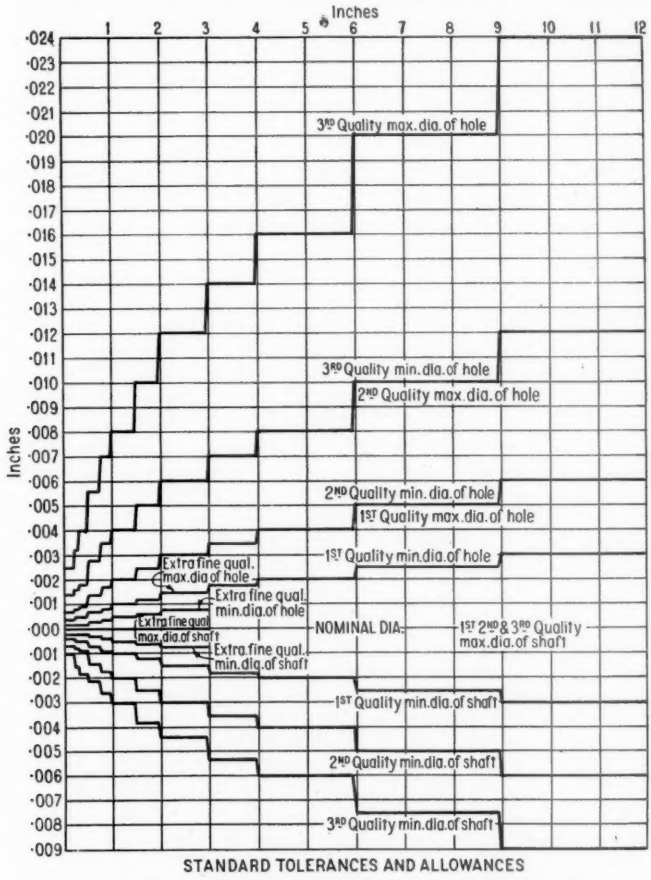

Inches
1 2 3 4 5 6 7 8 9 10 11 12
·024 ·023 ·022 ·021 ·020 ·019 ·018 ·017 ·016 ·015 ·014 ·013 ·012 ·011 ·010 ·009 ·008 ·007 ·006 ·005 ·004 ·003 ·002 ·001 ·000 ·001 ·002 ·003 ·004 ·005 ·006 ·007 ·008 ·009
Inches
3RD Quality max. dia. of hole
3RD Quality min. dia. of hole
2ND Quality max. dia. of hole
2ND Quality min. dia. of hole
1ST Quality max. dia. of hole
1ST Quality min. dia. of hole
Extra fine qual. max. dia. of hole
Extra fine qual. min. dia. of hole
Extra fine qual. max. dia. of shaft
Extra fine qual. min. dia. of shaft
NOMINAL DIA.
1ST 2ND & 3RD Quality max. dia. of shaft
1ST Quality min. dia. of shaft
2ND Quality min. dia. of shaft
3RD Quality min. dia. of shaft
STANDARD TOLERANCES AND ALLOWANCES

Fig. 12.—A chart of standard tolerances and allowances.

is adopted, the hole is made approximately standard size with tolerance only to cover errors in workmanship. The allowances for various fits are obtained by varying the shaft sizes. It is necessary now to fix the limits of tolerance of the hole in relation to its standard size.

There are two distinct systems obtaining to-day, called :—

(1) *The bilateral system.*
(2) *The unilateral system.*

These two systems may again be sub-divided—

(1) *The bilateral system.*

(a) The tolerance placed symmetrically on both sides of the standard hole.

(b) The major portion of the tolerance above and remainder below the standard hole.

(c) The major portion of the tolerance below and the remainder above the standard hole.

(2) *The unilateral system.*

(a) The standard hole is the minimum with all the tolerance above the nominal size.

(b) Same as case (2) (a) with tolerance all below standard hole.

The Newall system, which has been in use for a large number of years embodies the bilateral system for both classes of holes, viz., (a) and (b) classes, and the major portion of the total tolerance is above the standard size.

It is contended that as the "go" end of the limit gauge should pass easily into the hole, whilst of course the "not go" end should not enter and, therefore, if the "go" end of the gauge is slightly undersize, the hole will be slightly bigger than the gauge and will approximate to standard size. On the other hand, in an admirable paper entitled "Should the nominal line be represented by one of the limits or should it lie in the centre of the area of limits" by Johansson, this question is dealt with very fully, and the author of the paper states a good case for the bilateral system where the limits are symmetrical about the standard hole size.

There is, however, to-day, a slight bias in favour of the unilateral system, where all the tolerance is plus. In preparing a limit system in order to establish satisfactory limits for inspection, the disposition of the hole tolerance must be settled, having regard to the kind of work being produced and also to the gauges already available, if any.

Tolerance.—It has been proved that it is not necessary or economical to endeavour to obtain a higher degree of accuracy than is needed to enable manufacturers to build, say, a thoroughly efficient machine, although each particular part is not made as accurately as it could be, if desired. The tolerances, therefore, should be as large as possible, and in fixing them consideration should be given to—(a) the length of engagement; (b) the size of the work; (c) the quality of the finish; and (d) the allowance (kind of fit).

In deciding the steps of limits both for the shafts and holes for various sizes, it is recommended that these should be fixed in multiples of 0.0004in., as this represents 0.01mm., and the system, therefore, can be used for metric or English dimensions. This applies particularly to the check gauges or standard Johansson slips, as one set can be used to check gauges made under either the English or metric system.

In deciding on the tolerance for a certain class of work, the hole may be considered separately and then the shaft; or the sum of the tolerances for shaft and hole may be decided and then divided

between the shaft and hole in such a way as is considered best suits requirements.

In a paper presented by Mr. R. Dumas to the British Engineering Standards Association, an expression is given for the sum of tolerances, which forms a basis of a system of limits.

$$Y = \text{Sum of tolerances.}$$

Then

$$Y = K + a\sqrt{-D} + bA.$$

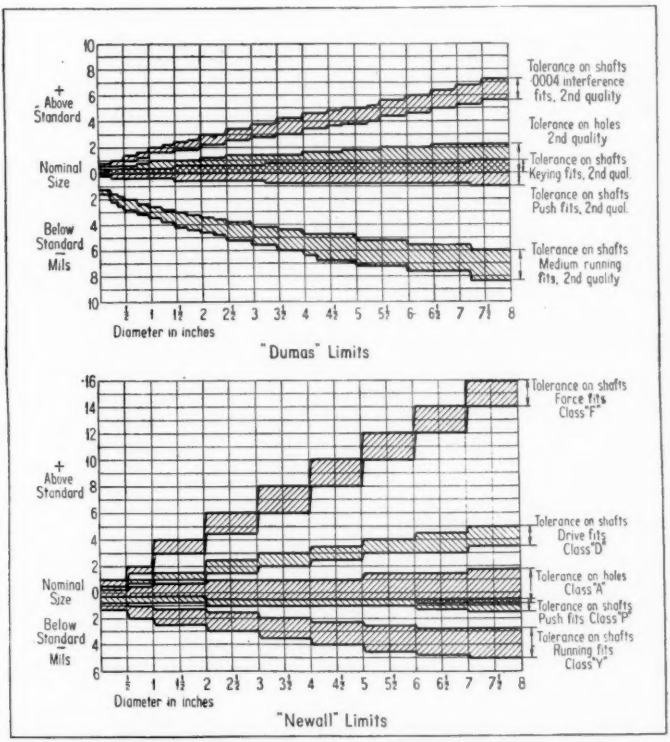

+ Above Standard
Nominal Size
Below Standard Mils
Diameter in inches
"Dumas" Limits
Tolerance on shafts 0004 interference fits, 2nd quality
Tolerance on holes 2nd quality
Tolerance on shafts Keying fits, 2nd qual.
Tolerance on shafts Push fits, 2nd qual.
Tolerance on shafts Medium running fits, 2nd quality
"Newall" Limits
Tolerance on shafts Force fits Class "F"
Tolerance on shafts Drive fits Class "D"
Tolerance on holes Class "A"
Tolerance on shafts Push fits Class "P"
Tolerance on shafts Running fits Class "Y"

Fig. 13.—Chart showing Dumas and Newall systems of limits.

where K, *a* and *b* are factors which vary according to the quality of the work, but which are constant for each quality—

D = Dimension under consideration in inches.

A = Allowance, which is the minimum difference between shaft and hole, in thousandths of an inch.

A limit system for second quality work built up on this system is

shown in fig. 13, and the Newall system of limits is also shown in the same figure.*

Allowance.—The allowance for any prescribed class of fit must be allocated having regard to the limits of the tolerance.

It is of considerable importance whether the basis of a system of limits is built up on the mean allowance or the minimum allowance.

For example, assume a running fit is required between a shaft and bearing of 3in. nominal diameter. Assume limits on hole are :—

+0.0008in. high limit.
−0.0008in. low limit.

Tolerance is 0.0016in. Mean size of hole equals 3.000in.

Assume limits on shaft are :—

+0.0012in. high limit.
−0.0028in. low limit.

Tolerance is 0.0014in.

$$\text{Mean allowance} = \frac{0.0012 + 0.0028}{2} = 0{\cdot}002\text{in.}$$

Hence, on the basis of mean allowance, the clearance is 0.002in., which is a reasonable allowance for a medium class fit.

But now consider the minimum allowance.

The smallest hole is 2.9992in. The largest shaft is 2.9988in.

Hence, the minimum allowance is only 0.0004in., which is a very small allowance for a running fit.

It is not enough to say that by the use of limit gauges there is tendency to produce a "mean size," for when the limits are fixed there is ample opportunity for work to be produced on the extreme of the limits. The standard table of limits issued to the drawing office and the works should be clear, and so arranged that they can be understood without a book of instructions.

General Limits.

The following directions on limits have been drawn up as part of a works system and have proved very satisfactory in practice :—

Limits.—Where limits are given on drawings, they refer to dimensions of the "go" and "not go" limit gauges required for the dimensions in question, and to which there must be rigid adherence. Dimensions of parts on which limits are not given on the drawings must be within the following general limits :—

(a) Where the diameter of bolt holes is given as $\frac{1}{32}$in. clearance, the position of, or dimension between any and every two bolt or tapped holes must be within + or −0.0075in. or 0.2 mm.

(b) Where the diameter of bolt holes is given as $\frac{1}{64}$in. clearance, the position of, or dimension between any and every two bolt or tapped holes must be within + or −0.004in. or 0.1 mm.

(c) *General limits on diameters of drilled holes.*

Size of Hole.	*Tolerance applied in thousandths.*
From 0 to $\frac{1}{4}$in.	0 plus $2\frac{1}{2}$
,, $\frac{1}{4}$,, $\frac{1}{2}$in.	0 ,, 5
,, $\frac{1}{2}$,, 1in.	0 ,, $7\frac{1}{2}$
Over 1in.	0 ,, 10

* Proceedings of the Manchester Association of Engineers—from a paper by Rhodes on "Workshop Measurements."

(d) Thickness of castings where not machined are to be within size and + 10 per cent. of given thickness.

(e) Thickness of castings where machined on one side only, are to be within size and + 5 per cent. of given thickness.

(f) Diameters, lengths and thickness of castings, where machined on both sides, also other bright turned metal parts are to be within size + or −0.0075in. or 0.2mm.

(g) All screw threads for bolts and nuts are to be of standard Whitworth or metric form. The tolerances on the dimensions of the elements of the screw threads for such bolts and nuts are to be within those laid down in the B.E.S.A. Report.

The tolerance on the actual effective diameter of such screwed parts must be within size plus or minus an amount equal to $0.02\sqrt{\text{pitch}}$, and this tolerance must include any allowance for pitch and angle error such that the virtual effective diameter is also within the same limits. The limits on bolt or plug work will be size to minus and on nuts or screwed holes size to plus.

It is impossible to exhaust the subject of limits in these notes, but the fixing of satisfactory limits is so important in regard to efficient inspection that the author has considered that this paper would not be complete without some reference to the matter.

Limits on Drawings.

The dimensions of the various details of a machine which are fixed beforehand are the nominal sizes, and consequently the nominal sizes should be shown on the drawings. The author is of the opinion that no system of dimensioning drawings should be used which has a tendency to obscure the nominal size.

Gauges are not always available in the shops, and if they were, micrometers are still preferred and extensively used for some operations.

For example, in grinding a shaft the operator requires to ascertain how much has been left for grinding. A rough cut is usually taken—removing the tool marks—and the work measured. It is necessary, therefore, that the operator should know the maximum and minimum sizes of the work.

If the limiting dimensions be shown on the drawing by a symbol, a table must be referred to, which entails extra work, and a possible chance of error.

There are two distinct methods of showing the nominal dimensions:

1. By whole numbers and fractions, e.g., $2\frac{9}{32}$.
2. The decimal system.

It is not proposed to discuss this point in these notes, but either may influence the method adopted of indicating limits.

A study of fig. 14 will show that the same limits are shown in five different ways. (Newall B. hole with class X running fit.)

Taking each case illustrated—(A) the unit of 0.001 is used for expressing the limits—the final size of the work is a simple calculation.

(B) The Newall method where the limits are indicated on the drawing by a symbol, and the values are obtained by further reference to a table of limits.

The objections to this system are:

1. Opportunity of error in translating the symbol when limit gauges are not available.
2. Difficulty of showing all combination of length dimensions within the capacity of the tables.

(C) The limiting dimensions are given direct: This method tends to obscure the nominal size, and is rather cumbersome.

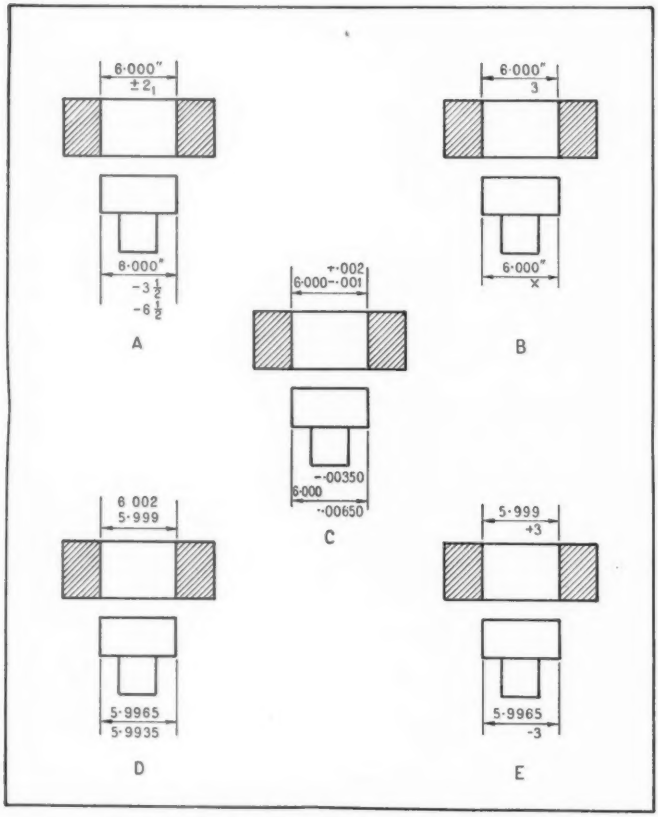


Fig. 14.—Methods of indicating limits on drawings.

(D) Is sometimes referred to as Lanchester's method: The maximum or the minimum size is given with either a plus or minus tolerance, the unit being 0.001, as in case (a).

In the illustration in fig. 14 the shaft is given with its maximum dimension, and a minus tolerance, and the hole, its minimum dimen-

sion with a plus tolerance. This method of dimensioning is worthy of a little consideration, for it is quite clear that the dimension given to the shaft and the hole, quite apart from the tolerance required in manufacture, shows at a glance the absolute minimum difference between the two parts. It shows immediately the amount of initial play as between the shaft and the bearing, which is either necessary, or which, on the other hand, must be tolerated, because it is impossible to work to the finer limits.

It is strongly advocated by some investigators that limit systems should be built up entirely on the consideration of the minimum differences, as clearly shown in this method of dimensioning drawings.

Inspection of Screw Threads.

There are so many questions relating to the gauging and inspection of screw threads that it is absolutely impossible to cover the whole ground of this subject in these notes. A very large amount of work has been done on this subject, and from time to time several investigators have published their results.

Very complete notes dealing with screw gauges and other matter appertaining to screw threads are published by the National Physical Laboratory, and much useful information is contained therein.

In dealing with screws there are a number of elements involved which make it rather difficult to see at a glance exactly what are the governing factors of satisfactory screw threads. An examination of the problem, however, will clearly reveal that in the case of a screw thread, where more than one element is controlling the ultimate result, it is axiomatic that each of these elements should be considered separately, while they should also be considered collectively, in so far as their relationship to one another is concerned.

Tolerance.—Tests have been carried out by the National Physical Laboratory to ascertain the effect of excessive tolerance on the strength of a nut and bolt, and it is found that large tolerances do not appear to have any material effect on strength until they reach something in excess of 20 per cent. of the depth of the thread. This clearly indicates that where there are no other controlling factors, comparatively large tolerances may be allowed without having any deleterious effect on the strength of the bolt.

In fig. 15 is given a chart which shows the amount of maximum tolerance plus allowance permitted on a British standard fine screw thread, as recommended by B.E.S.A. in Report No. 84. A uniform allowance of 0.002in. has been made throughout between the maximum bolt and the minimum nut.

In the inspection of screw threads on a commercial basis, as distinct from the inspection of screw gauges, it is essential that some simple system should be used in employing the minimum number of gauges consistent with satisfactory results.

There are several instruments made to-day for measuring the effective diameter and other elements of the screw thread, which are too complicated to be used commercially.

The following are definitions of the principal elements of a screw thread :

Effective diameter of a screw.—The effective diameter of a perfect screw having a single thread is the length of a line drawn through the axis and at right angles to it, measured between the points where the line cuts the flanks of the thread.

Core diameter.—The core diameter is twice the minimum radius of a screw, measured at right angles to the axis.

Full diameter.—The full diameter is twice the maximum radius of a screw, measured at right angles to the axis.

Crest.—The crest is the prominent part of the thread, whether of the male screw or of the female screw.

Root.—The root is the bottom of the groove of the thread, whether of the male screw or of the female screw.

Flank of thread.—The flank of the thread is the straight part of the thread which connects the crests and roots.

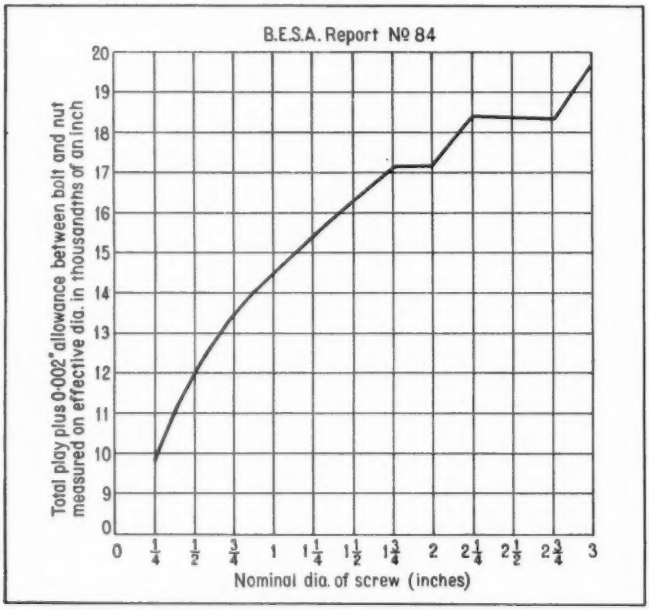


Fig. 15.—Chart showing maximum tolerance plus allowance on British standard fine thread.

Angle of thread.—The angle of the thread is the angle between the flanks, measured in the axial plane.

Pitch.—The pitch is the distance in inches or millimetres measured along a line parallel to the axis of the screw between the point where it cuts any thread of the screw and the point at which it next meets the corresponding part of the same thread. The reciprocal of the pitch measures the number of turns per inch or millimetre as the case may be.

The three principal governing elements of a commercially-produced screw are—pitch, effective diameter, and angle.

Pitch.—Pitch is difficult to measure by any direct method. It

can, however, be done by special machines which do not fall within the scope of ordinary inspection. It is usually considered that errors in pitch and angle can be met by a suitable alteration in effective diameter, provided this is not reduced beyond the minimum permitted by the tolerance. It is evident that errors in pitch and angle do not prevent interchangeability, provided a "go" gauge will pass over the screw, and provided also that the effective diameter is within the tolerance.

Effective diameter.—There are several methods of measuring the effective diameter. The common method is to use either small vee-shaped anvils with the aid of a micrometer, or to use standard rollers or needles, as they are often called, also in conjunction with

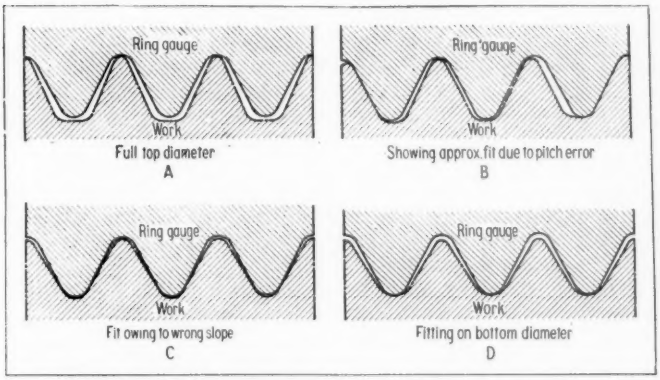


Fig. 16.—A ring gauge passing incorrect screw threads.

the micrometer. These methods, however, are laborious, and cannot be usefully employed in an ordinary inspection department.

Gauges.

The most common types of gauge are the screwed plug gauge and the ring gauge, which are well known. These gauges, however, must be applied with great caution.

In fig. 16 are shown four cases where the ring gauge would apparently be a satisfactory fit on an incorrect screw thread. The ring gauge is fitting for the following reasons:

(A) Top diameter is to size and the ring gauge is bearing on the crests of the thread.

(B) The threads are thin, but owing to a pitch error the gauge is apparently a good fit.

(C) The gauge is fitting on account of the slope of the thread being incorrect.

(D) The gauge is fitting on the bottom diameter only.

It will be seen, therefore, that, as already stated, to make sure a screw thread is correct all the elements should be inspected separately with a "not go" gauge, and collectively with a "go" gauge.

A suggested set of gauges to carry into effect this method of gauging is shown in fig. 17. Provision is made for measuring all the elements collectively, whilst a " not go " gauge measures them all separately. The gauge for measuring the effective diameter is not interfered with by errors of pitch, because there is only one convolution on the gauge.

Another commercial method of inspecting screw threads is to have only standard plug and ring gauges for measuring the thread, whilst the outside diameter of a bolt, say,, would be measured with an ordinary snap gauge or micrometer, and the root diameter of screwed holes be measured with an ordinary " Go " and " Not go " plug gauge.

In order to check the form of the thread, and particularly the

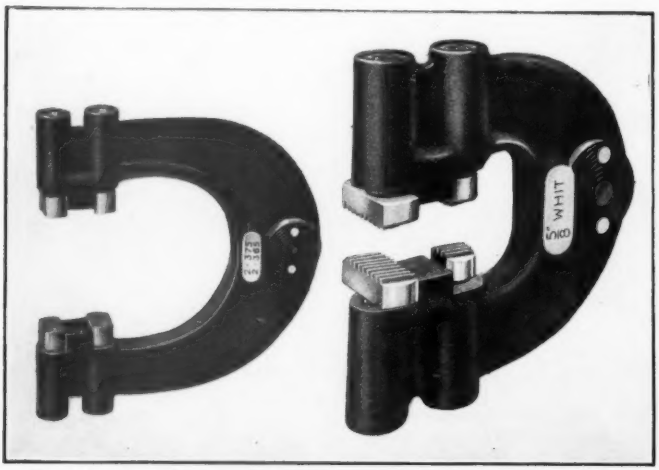


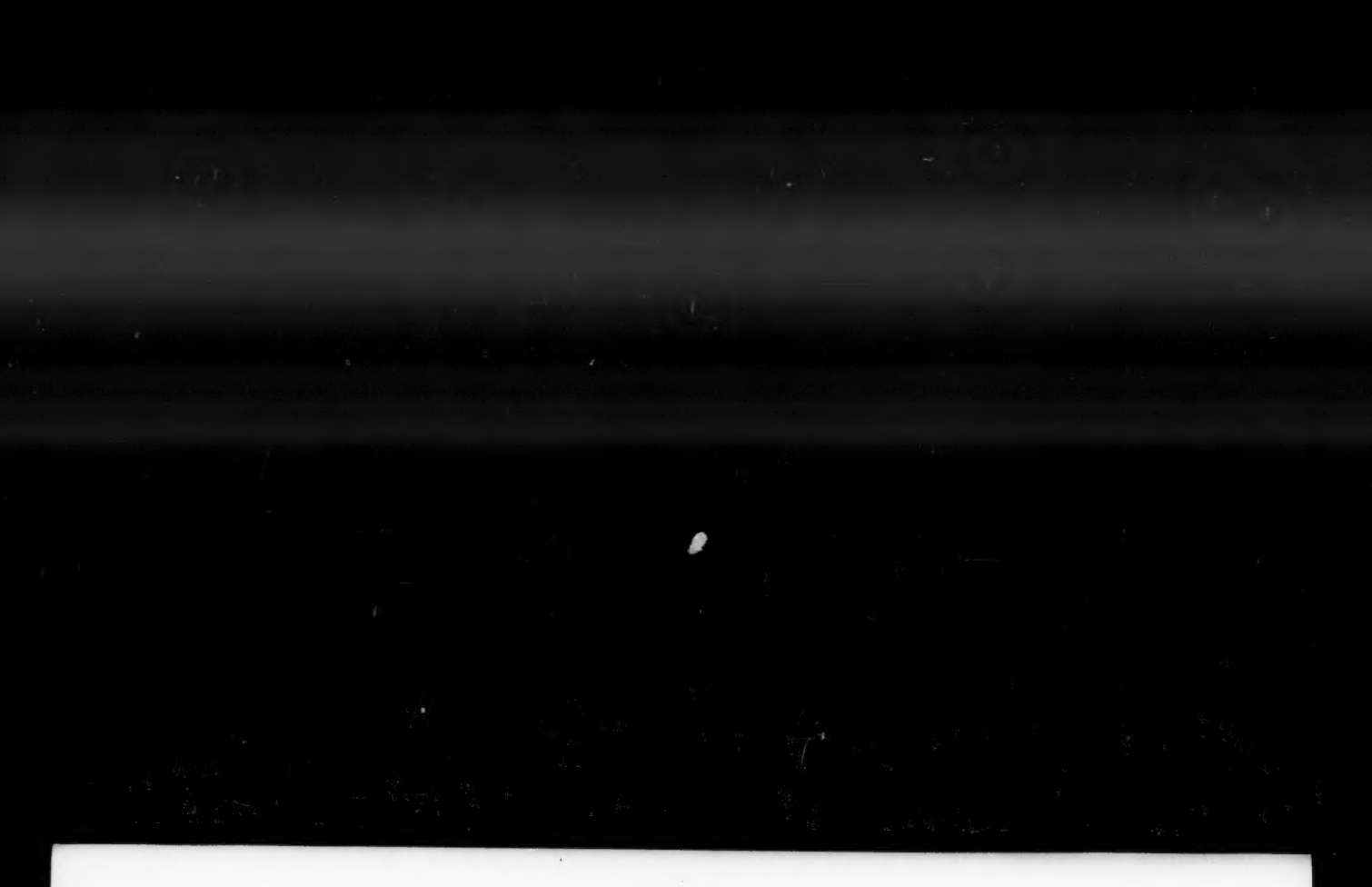
Fig. 18.—The Wickman adjustable plain and thread snap gauges.

effective diameter, pitch, and angle, a proportion, say 1 per cent., could be projected on to a screen fifty times full size by means of a projection apparatus.*

It is considered that the latter method is quite commercial, and produces very good results. Usually screw threads are made by means of taps and dies, and if the first samples produced by the tools are carefully inspected by this method, it is only necessary to make sure that the tools are cutting good threads consistently by projecting a small percentage in order to control the three elements involved.

A very useful type of gauge is the Wickman adjustable thread snap gauge, shown in fig. 18. Its principle is to measure collectively the pitch, effective, major and core diameters of a screw thread.

* This apparatus is described fully in a pamphlet issued by the National Physical Laboratory.



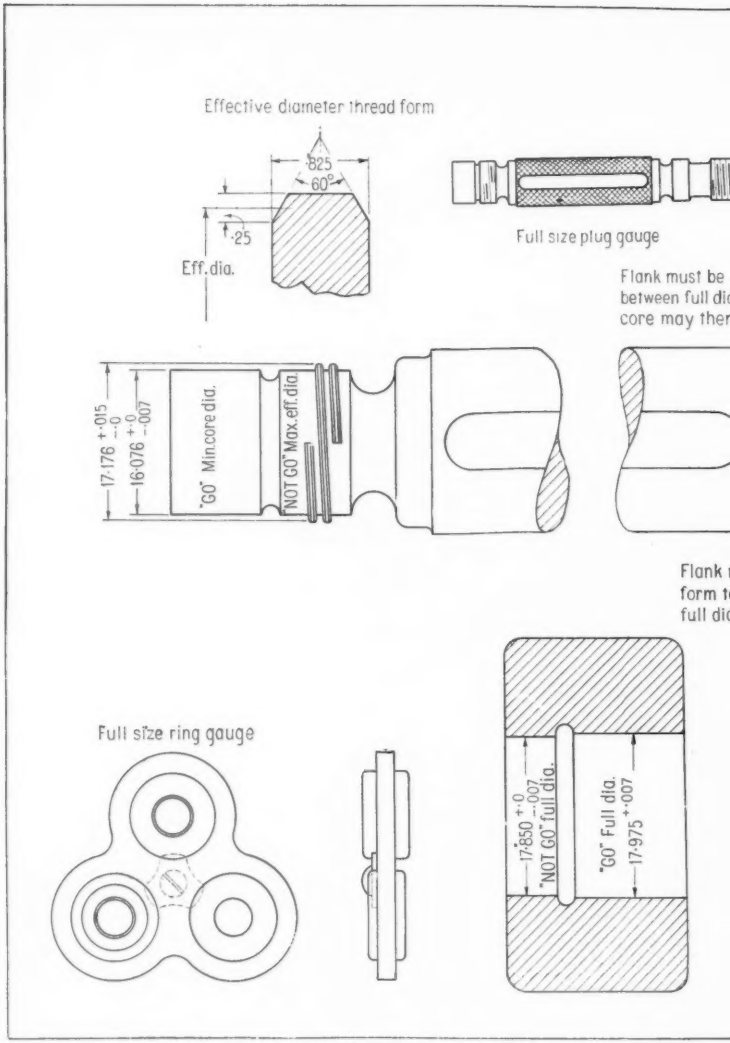
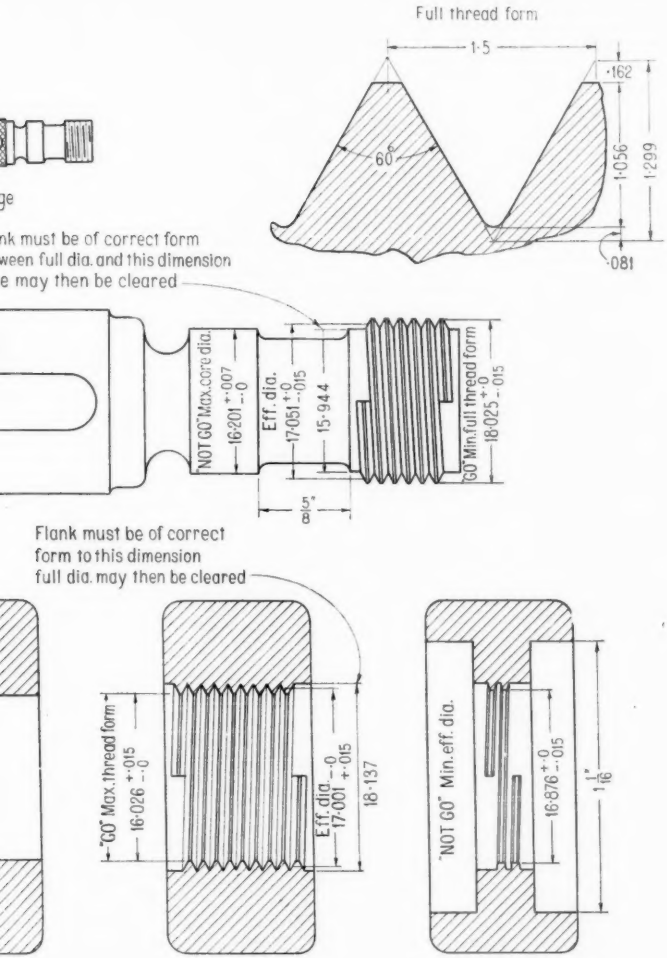


Fig. 17.—A set of gauges for measuring, separa



ng, separately and collectively, screw elements.

[*To face p. 294.*

The outside pair of anvils which form the front portion of the gauge are produced very accurately, and represent a section of a perfect ring gauge. If a screw can pass through them, it will be obvious that no element of the thread is larger than the nominal.

It is still necessary to make sure that the effective diameter is within the limits of tolerance, and this is checked by the two "not go" anvils situated at the rear of the "go" anvils. If the threads have been thinned in order to correct pitch error, the screw will then pass the "not go" gauge, and will, of course, be rejected. Should the screw be unable to pass the front pair of anvils, it is quite simple to hold the screw thread up to the light when it can be readily seen which element is in error.

In the manufacture of inspection gauges, it is necessary to work to fairly fine tolerances, and a list of tolerances for inspection gauges is shown in fig. 19.

A full list of tolerances for screw threads is given in the B.E.S.A. Report No. 84, whilst this is supplemented by another report, No. 95, giving useful tables for the corrections of effective diameter required to compensate pitch and angle errors in screw threads of Whitworth form.

Inspection of Gears.

There is an ever-growing demand for accurately cut gears. Accuracy usually denotes efficiency, minimum wear, and silence.

Technical progress, and the increasing degree of perfection in the cutting of gear-wheels, demands similar progress in inspection methods.

Most engineers know what constitutes a good gear, but few know how to produce one, and still fewer take the trouble to institute inspection methods to determine whether a gear is sufficiently accurate for the purpose intended.

In a recent paper entitled "Notes on Motor Car Gear Boxes," read before the Institute of Automobile Engineers by Mr. H. F. L. Orcutt, the importance of accurate gears is emphasised. The author of the paper states: "Gears which are of known uniformity and quiet running should pass the following inspection:—

"1. Satisfactory hand-roll of mating gears at fixed centre-distances.

"2. Power tests for noise at high speeds with mating gears accurately mounted at fixed standard centre-distances.

"3. Backlash, so that gears run freely without jamming. Backlash need not be to fine limits when tooth forms are correct.

"4. Eccentricity must be within fine limits. It should not be more than 0.002in. in any gear in the ordinary transmission-box.

"5. Index errors (by which is meant the pitch spacing of the working faces) must be such that they cannot be detected under ordinary methods of inspection.

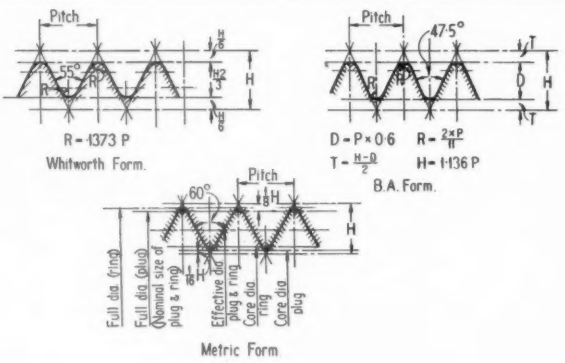
"6. Tooth shapes must be as near standard as possible, showing on hand-roll or on power test with the mating gear, a bearing over the whole working surfaces of the teeth.

"7. The finish must be smooth. A roughly finished tooth is not as quiet as a smooth one."

Where gears have to run quietly under heavy loads, only very

small errors are permissible. In fact, these errors are so small that they cannot always be detected by ordinary methods.

Like many other parts of mechanism, a gear contains several elements, each of which must be accurate, and, moreover, be



TOLERANCES FOR INSPECTION GAUGES, SCREWED PLUGS ONLY						
	UP TO 25 MM OR 1" DIA		25 MM TO 50 MM OR 1" TO 2"		OVER 50 MM OR 2"	
FULL DIA	+0 −0·015 M.M.	+0 −0·0006"	+0 −0·02 M.M.	+0 −0·0008"	+0 −0·025 M.M.	+0 −0·001"
EFFECT DIA	+0 −0·015 M.M.	+0 −0·0006"	+0 −0·025 M.M.	+0 −0·001"	+0 −0·036 M.M.	+0 −0·0014"
CORE DIA	+0 −0·02 M.M.	+0 −0·0008"	+0 −0·025 M.M.	+0 −0·001"	+0 −0·036 M.M.	+0 −0·0014"
PITCH OVER LENGTH OF THREAD	± ·008 M.M.	± ·0003"	± ·013 M.M.	± 0·0005"	± ·018 M.M.	± ·0007
ANGLE	IN ANGLE THE PERMISSIBLE ERROR DEPENDS ON THE PITCH AND VARIES FROM ± 1·5° IN FINE PITCHES TO ± ·5° IN MEDIUM AND COARSE PITCHES.					

For reference gauges one-half the above tolerances are allowed.

The above errors in pitch and angle can be tolerated only if accompanied by a suitable reduction in the effective diameter, which, however, must fall within the limits of tolerance given for this element in the Table.

The tolerances on ring gauges are positive and equal in magnitude to those on the corresponding elements of the plug, *e.g.*, the tolerance on core diameter of the ring is equal but opposite in sign to that on the full diameter of the plug.

Fig. 19.—A chart showing the fine tolerances necessary for inspection gauges.

correctly placed in relation to one another. For example, a profile of a gear tooth of involute form must be correct. No approximation has been found which is as satisfactory as a true involute.

It is of no use, however, producing gears of correct involute form,

if, say, the teeth are not parallel with the axis of the gear. For a gear to be satisfactory the author has found, as the result of practical tests, that errors must be reduced to an absolute minimum.

(1) Spacing of teeth.—No measurable error must exist.

(2) Thickness of different teeth at pitch line on same gear must not vary more than 0.0005in.

(3) Bearing along tooth not less than 85 per cent. of width of tooth.

(4) Pitch diameter must be true, within an eccentric allowance of 0.001in. maximum.

As a result of the progress in producing gear teeth, several gear-testing jigs have been developed.

In fig. 20 is shown a testing jig, used for spur and helical gears, made by Messrs. J. Parkinson & Son, Shipley.

There is a scale fitted to the fixed slide and a vernier to the floating slide, so that the actual centres of the gears may be compared with the running centre distance.

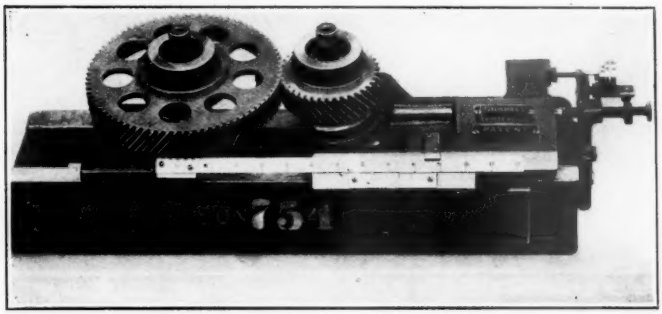


Fig. 20.—The Parkinson spur and helical gear testing jig.

The dial indicator at the right-hand end of the bed indicates the movement of the floating slide on which one gear is mounted.

A similar appliance made by the same makers, but for bevel gears, is illustrated in fig 21.

This type of jig is useful and has its purposes if a variety of gears are to be inspected.

Where quantities of gears are being made and the expense is justified, fixed centre jigs should be made, as shown in fig 22. On these jigs backlash is measured by inserting feelers between the teeth of the mating gears.

Adjustable jigs are always liable to wear, and although they may be overhauled frequently, errors accumulate, due to dirt and wear, and they are never as accurate as the fixed centre jigs.

Errors due to pitch and profile can only be detected by hand rolling the gears on fixed centres and only then after constant practice. It is possible to set up a relation between all the foregoing tests and results obtained on a power test under load. The power test is made by mounting a pair of gears on spindles, carefully fitted in a sub-

stantial bearing and dead parallel. The driving spindle revolves about 1,000 r.p.m., and the driven spindle is fitted with a brake. Any inaccuracies which have been overlooked are soon apparent on this test.

Inspection of gears should be systematic and thorough. After a gear-cutting machine has been set up the "first off" should be inspected before the bulk of the gears is proceeded with. If proper inspection jigs be available—as they should be—very little time is actually lost, and probably a considerable amount of scrap is saved.

Inspection Gauges. (Plain Cylindrical Work).

In the design of gauges for all purposes there is sufficient scope to exercise the utmost ingenuity on the part of the designer. It is

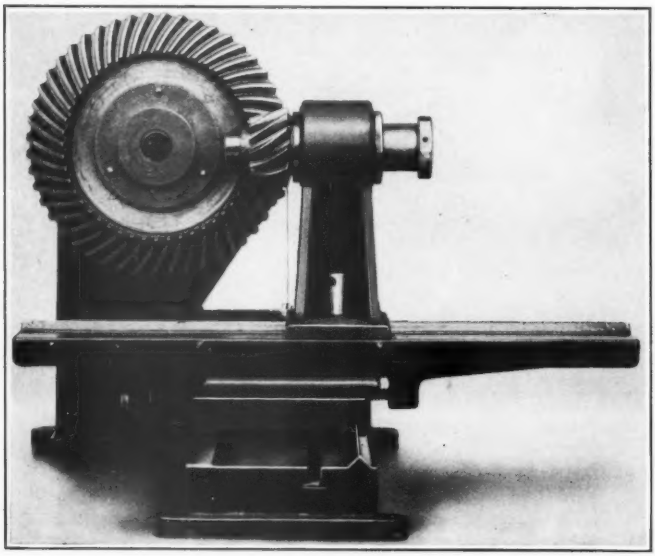


Fig. 21.—A bevel gear testing appliance by Messrs. Parkinson.

impossible to deal with the design and application of gauges in all their aspects in these notes, but there are a few fundamental points which are applicable more or less to all types of gauges.

There are several kinds of gauges, which may be referred to as follows :—

(1) *Limit gauges.**—Gauges for ensuring that any given dimension is within the tolerance laid down for the class of work to be produced. In the case of cylindrical work these gauges may be

* See B.E.S.A. Report No. 27, 1906.

either double plug gauges, one end of which must enter, and the other end of which must not enter the hole to which it is applied, or they may be either two-ring or two-gap gauges, one of which must pass over, and one of which must not pass over the shaft to which they are applied.

(2) *Standard gauges.*†—A standard gauge is a gauge made as accurately as possible to its nominal dimensions and suitable for depositing with some recognised authority, such as the Board of Trade or the National Physical Laboratory, for purposes of ultimate reference.

(3) *Reference gauges.*†—A reference gauge is similar to a standard gauge, but is intended for use by manufacturers or others. Reference gauges are verified, and their accuracy certified, by the National Physical Laboratory.

(4) *Inspection gauges.*†—Gauges used by inspectors to check the accuracy of the work and determine if it is within the limits laid

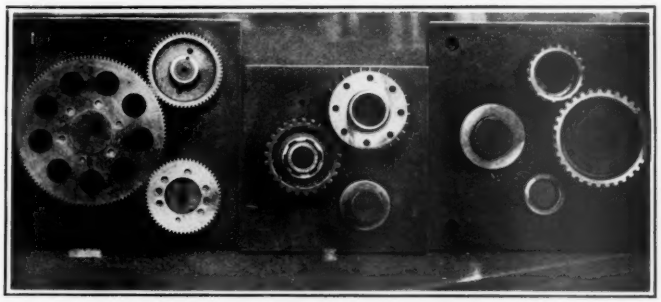


Fig. 22.—Jigs with fixed centres for testing gears.

down. They are verified and their accuracy certified by the National Physical Laboratory.

(5) *Shop gauges.*†—Gauges used in the workshop to control manufacture and verified from time to time, either by comparison with reference gauges or by the use of suitable check gauges. Alternatively, they may, if desired, be sent to the National Physical Laboratory for verification.

(6) *Check gauges.*†—Gauges used for verifying the accuracy of other gauges. Generally speaking, they are of opposite form to the gauges they are intended to verify—e.g., the check for a ring gauge is a plug, and *vice versa*. Check gauges may be further sub-divided into standard check gauges and shop check gauges, following the definitions given above.

(7) *Master gauges.*†—Gauges used only in the manufacture of, or for the purpose of verifying, check gauges. They are again of opposite kind to the check gauges, and in some cases standard or reference gauges will serve as master gauges. More frequently, however, master gauges, when required, have to be specially designed.

† *Ibid.* No. 84, 1918.

Tolerances are allowed in the manufacture of the gauges themselves, over and above the tolerances which the gauges are made to cover. The main point involved is to make quite sure that work made to the workshop gauges will be accepted by the inspection gauges. The tolerances on shop gauges should be such that all work passed by them is necessarily between the specified limits of size. Therefore, in making workshop plug gauges if any tolerance is required it is usually made plus on the " go " end gauge and minus on the " not go." In the case of a gap gauge, the tolerance allowed is usually plus on the " go " and minus on the " not go."

For inspection gauges these gauge tolerances are reversed, thus ensuring that all work made to the workshop gauges will be accepted by the inspection gauges. The tolerances recommended are $\frac{1}{4}$ of the tolerances on the work. If the " go " end of the gauge is 0.001 smaller than " not go " end, the permissible tolerance on the gauge is 0.0002, plus or minus as the case may be.

Plug Gauges.

Plug gauges are generally used for holes up to about 3in. diameter. The "go" end of the gauge, as shown at F in fig. 23, in all cases is longer than the "not go" so as to avoid confusion between the two ends of the gauge.

The gauges should be kept as light as possible, and the smaller sizes are usually made from cast steel, containing about 0.9 to 1 per cent. carbon, and are hardened throughout. The larger sizes are usually made from mild steel, case-hardened and ground. In some shops the gauges are made from high-speed steel, as it is found that in certain circumstances they are better than in any other kind of steel.

For large size holes, pin or bar gauges are generally used, as it is found that plug gauges of very large diameter are very difficult to manipulate owing to their weight and the difficulty of maintaining a large gauge " square " in the hole. For very large holes sometimes what is known as a " wobble " gauge is used. The application of this gauge is shown in fig. 24. The gauge is pointed, and is usually made to the size of hole or the low limit, and the diameter of the hole is measured by the amount the gauge moves sideways, as shown by the distance x in the diagram.

There is also another type of gauge used for holes, which is just an ordinary flat plate, anything from $\frac{1}{4}$in. to $\frac{1}{2}$in. wide, which is ground cylindrical, and this type of gauge is also much easier to handle than a large plug gauge. This type of gauge is shown at H in fig. 23.

Snap Gauges.

Snap gauges are made in different forms, but the standard form is a double-ended gauge, as shown at D in fig. 23. To avoid any possibility of confusion between the "go" and "not go" ends, the gauge faces of the "not go" are always shorter than those of the "go."

There are several other forms of external limit gauges, or snap gauges, which are shown in fig. 23.

It is usual to have standard forgings made, and it is then only necessary to machine out the gap of the gauge to the necessary

limits. These gauges are chiefly used by the inspection department, and for rough turning in the works.

A useful form of snap limit gauge, known as the "Wickman adjustable plain snap gauge," is shown in fig. 18.

The adjustable pins have a sliding motion and cannot rotate. This is a useful point, as there is no tendency for the adjustable pins to get out of square as they are always maintained parallel.

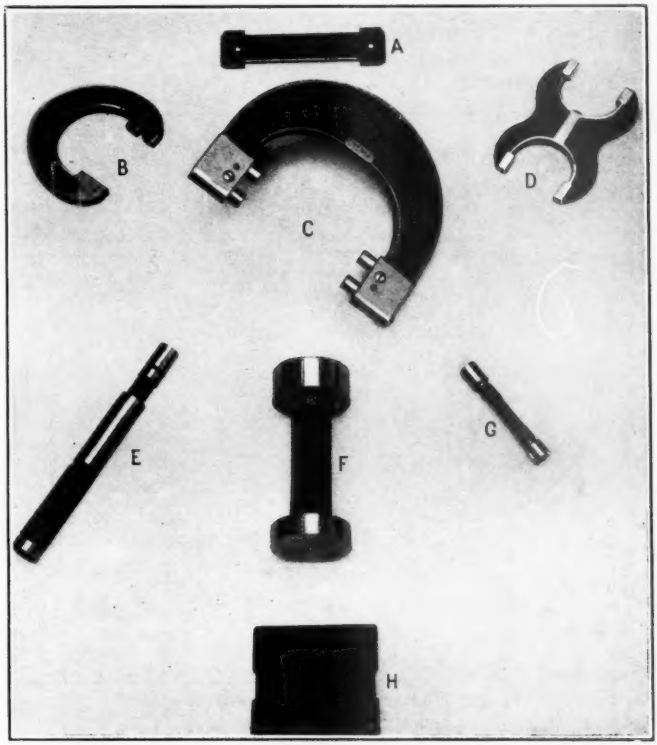


Fig. 23.—A typical group of inspection gauges.

The frame is of cast-iron with a section sufficiently strong for ordinary use.

Should any attempt be made to tamper with the gauge by closing it in, the frame will break. After adjustment the pins are locked and sealed, thus preventing any unauthorised alteration.

For accurate turning and precision grinding, the micrometer is still preferred, but the limit snap gauge is a very quick and accurate

method of checking work in the inspection department. Some snap gauges are made with cast-iron frames with hardened steel adjustable points, being constructed on the principle that it is far better for the cast-iron to break than to deflect. It is often found in practice, however, that even cast-iron will distort, and therefore it is recommended that the gauges should be made of steel, which is more or less unbreakable, with a section sufficiently strong to avoid distortion if the gauges are handled with reasonable care.

Description of Inspection Gauges shown in Figure 23.

(A) Snap gauge made from cast steel about $\frac{1}{8}$in. thick, which is used for gauging very shallow spigots.

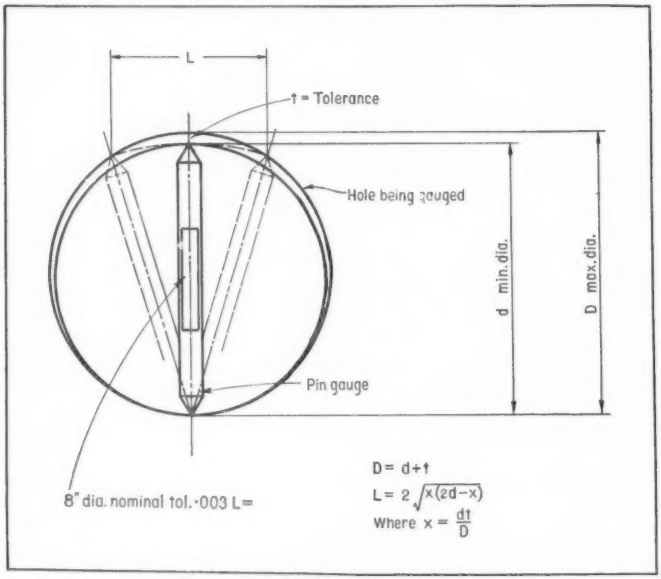


Fig. 24.—The application of a wobble gauge.

(B) Limit snap gauge with one jaw stepped, the "go" size being in front of the "not go" size.

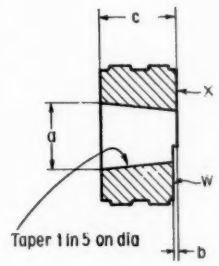
(C) A large gap gauge, similar to (B), except that the points are adjustable.

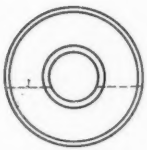
(D) Standard double-ended external limit gauge.

(E) This is a special gauge. One end is a "go" and "not go" gauge for a small hole. The other end is a "not go" end for a larger hole, whilst in the centre is the "go" gauge for the larger hole, and at the same time the gauge is used for checking the alignment of the two holes.

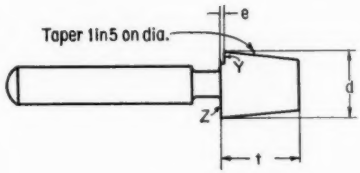
(F) and (G) Standard "go" and "not go" plug limit gauges.

(H) A modified form of plug gauge for a large hole. Reference has already been made to this gauge. It consists of a piece of cast steel ½in. thick, ground cylindrical. It can be seen from the illustration that the "go" and "not go" ends are separated. It is contended that this gauge is much easier to handle than a very





DIMENSION	M.M.	LIMITS MAX.	LIMITS MIN.
		M.M.	M.M.
a	15·05	0·01	0·00
b	0·25	0·00	0·01
c	15·25	0·01	0·00



DIMENSION	M.M.	LIMITS MAX.	LIMITS MIN
		M.M.	M.M.
d	15·00	0·00	0·01
e	0·25	0·01	0·00
f	15·00	0·01	0·00

Fig. 25.—Standard forms of plug and ring taper gauges.

large diameter plug gauge. In a large number of cases it can be used with success, and of course it is very much cheaper to make.

Inspection Gauges for Tapers.

In gauging tapers, although errors are permitted on the diameter of the taper, either at the small or large end, these errors cannot be measured in the ordinary way by measuring the diameters, as the diameter obviously varies along the taper. Before measuring the taper for size it is necessary to make quite sure that the form of

the taper is correct. This is usually done by lightly coating the taper gauge with a little Prussian blue, and by slightly revolving the ring gauge on the work, or the plug gauge in the hole, and examining the work after removing the gauge to make sure that the taper is correct.

In order to measure the variations in the diameter, this is usually done by measuring the distance the gauge goes in the work, or, similarly, how far the ring gauge will pass over the work.

If the taper be large, the gauge will go inside beyond the surface of the work, and will project if the hole is too small.

Two standard forms of taper gauges are shown in fig. 25. The tolerance on the diameter a is measured by the step on the gauge

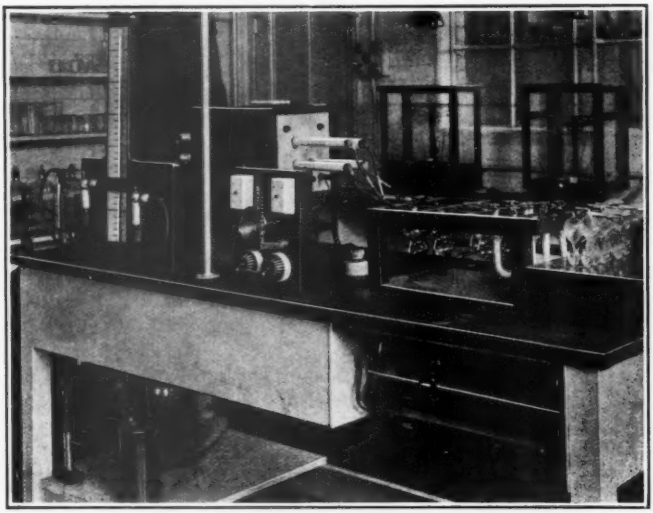


Fig. 26.—Special apparatus for determining carbon content of cast iron and steel.

distance b. When the ring gauge is pressed home a little by hand it should be a good fit on the taper, and the small end of the taper may project beyond the surface W, but not beyond the surface x. It will be seen from the illustration in fig. 25 that the distance b is 0.25 mm., and actually measures, assuming that the taper is correct, an error on the diameter a of 0.05.

Similarly, regarding the plug gauge, the face of the coupling which the gauge is measuring should, at the large end of the taper, project beyond the surface Y, but not beyond the surface Z.

Inspection of Materials.

In the earlier part of these notes the author briefly outlined a system of controlling material entering the works up to the point where it reaches the rough stores.

It is now proposed to deal briefly with a few of the practical aspects of the inspection and testing of raw material and material under heat treatment.

Stampings, Castings, etc.—All the important dimensions on stampings and castings should be checked and also examined for faults. In the case of castings, the patterns wear and often are broken in use, producing faulty castings. With stampings the dies wear, and it is found that the halves of the dies have not been correctly set in relation to each other, and the stampings are thus badly formed. This is important where jigs are in use, for in many cases the stamping must be reasonably correct or difficulties arise in the machine shop.

It is strongly recommended that special stamping drawings be prepared showing the necessary machining allowances. The stamp-

Fig. 27.—A micro-photographic installation.

ings should be inspected to these drawings, a copy of which has been supplied to the stampers. This procedure obviates any difference of opinion as to how much should be left on the stamping for machining.

Water Tests.—In many cases castings, such as cylinder blocks, are tested for porosity; this is usually done with water under pressure. The castings should be inspected carefully to make quite sure that all the sand is removed, and that the water passages are quite clear. A little soda should be added to the water to prevent rusting.

Physical Testing of Material.—The physical testing of material has of recent years become a very important part of workshop inspection. Engineers to-day expect a more exact knowledge of materials used by them in construction, and in many designs the factors of safety have been reduced consequent upon more specific

information of the materials used in construction. It is important, therefore, that materials should be supplied in conformity with the specification laid down. Most modern factories have now installed

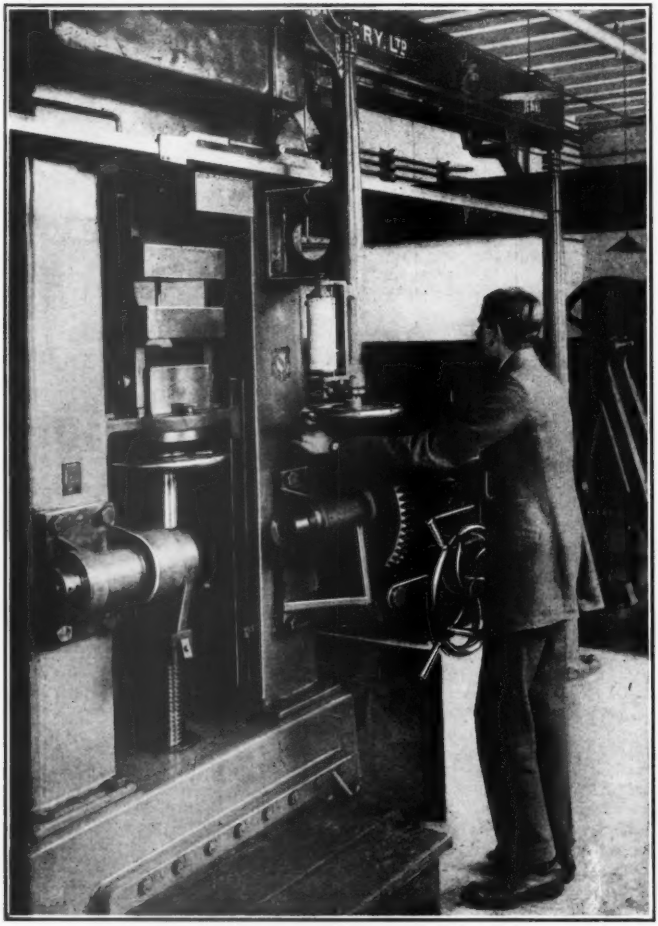


Fig. 28.—A tensile test machine in operation.

a laboratory and a physical test department, and interior views in these departments of a modern works are presented in figs. 26, 27, and 28.

Specifications.—Standard specifications should be adopted for the inspection of all material. These specifications may be specially prepared or existing ones may be used, as, for example, the British Engineering Standards Association Report No. 75.

Care must be taken not to specify any better material than is actually required, but when the specification has been drawn up, there should be strict adherence to the stipulated tests.

Marking of Drawings.—Several methods are adopted to show on the drawings the particular material of which a part is made—(a) To specify the kind of material and to put on the drawing the complete specification; (b) to specify the kind of material and the specification number; and (c) to specify simply:—"mild steel," "high tensile steel," or "brass," etc.

In the latter case a schedule is drawn up as shown in fig. 29, which represents a complete index of all material specifications for

CYLINDER & VALVES 8

DWG. No	PART	No OFF	A.B.SPEC.	MAT.
400	Cylinder	9	K 5	
401	Dome : Inlet valve	9	L 8	ALUM
402	Bush : Inlet dome	9	B 8	P.B
403	Valve : Inlet	9	K 9	N.C.S
404	Spring : Inlet valve	9	Nich. or app. Sp. St.	
405	Collar : Inlet valve	9	S 2	N.C.S
406	Split collar : valves. In. & ex.	27	S 14	C H S
407	Roller : ex val rocker	18	S 15	3% N

Fig. 29.—Material specification schedule.

use in construction. It is much easier to keep a schedule up to date than it is to recall and issue new drawings should the material specification be altered.

Physical Tests—Methods and Procedure.—It is necessary to control the amount of inspection carried out in the form of material testing. Much testing is undoubtedly carried out under conditions where a little organisation would reduce considerably the cost of testing. The tests should be sufficient to control heat treatment, and to verify that the steels used and supplied are in accordance with specification. The amount of testing will, of course, vary with the kind and quality of article being manufactured. Therefore, a material testing procedure should be carefully prepared, specifying the number of test pieces which are to be made for different parts of the machine, and the number of parts which may be represented by one test.

Material Testing Procedure.—A typical procedure for testing materials for an engine is set out on following page.

Bar Material.—Parts manufactured from mild steel or H.T. steel bar, which require no further heat-treatment, shall not be submitted to further material tests.

Mild Steel Stampings.—Provided no further heat-treatment is required, stampings shall be supplied in the normalised condition. If further heat-treatment is required, viz., after rough machining, tests in accordance with this schedule may be made. When, however, quantities of M.S. stampings of similar material and of approximately similar sections are normalised or heat-treated together, 2 per cent. of the test pieces shall be provided, but if the first pair of tensile and impact test pieces machined give satisfactory figures, the whole batch may be passed without the remaining test pieces being machined and broken.

Casehardened Parts.—Provided the bar, stampings, or forgings are made from materials which have been previously tested, fractured tests of samples or test pieces shall be made to test the condition of the core and the depth of the case. If such tests indicate unsatisfactory treatment the whole of the batch or box represented shall be rejected. Occasional tensile and impact test pieces shall be called for, at the discretion of the inspector, in order to check the treatment of the steel.

High Tensile Stampings and Forgings.—300. Crankshaft.—K.1.

Crankshaft.—Tensile and impact test pieces shall be provided with each shaft. Impact tests shall be made for each shaft, but only one tensile test piece per batch from the same cast heat-treated together shall be pulled, other shafts being Brinelled.

Oil-tempered Steel.—505. Connecting rod.—S34.

Two or three test pieces (tensile and impact) shall be provided for each batch of rods to be heat-treated together, but only one of each shall be broken, unless subsequent re-treatment is necessary. Both ends of each rod shall be Brinelled.

As an alternative, if the section of the rod is sufficient, a connecting rod representing a batch heat-treated together may be cut up, and impact and tensile tests made.

When quantities of H.T. stampings of similar material, to same specification, and of approximately similar sections, are heat-treated together, 2 per cent. of test pieces shall be provided, but if the result of the first pair of tensile and impact test pieces is satisfactory, then the batch of stampings may be passed on Brinell tests alone without further test pieces being machined.

Definitions.

The definitions presented below will be of use when arranging for the normalising and heat-treatment of stampings and other parts.

With reference to the upper critical range referred to in the definition of normalising, this is about 850° C. for an ordinary carbon steel, and 820° C. for nickel and nickel chrome steels. This point should be obtained by reference to the steel makers for each case.

1. *Normalising.*—Normalising means heating a steel (however

previously treated) to a temperature exceeding its upper critical range, and allowing it to cool freely in the air. The temperature shall be maintained for about 15 minutes, and shall not exceed the upper limit of the critical range by more than 50° Centigrade.

2. *Annealing.*—Annealing means re-heating followed by slow cooling. Its purposes may be :—

(*a*) To remove internal stresses or to induce softness, in which case the maximum temperature may be arbitrarily chosen.

(*b*) To refine the crystalline structure in addition to the above (*a*), in which case the temperature used must exceed the upper critical range as in normalising.

3. *Hardening.*—Hardening means heating a steel to its normalising temperature, and cooling more or less rapidly in a suitable medium, e.g., water, oil, and air.

4. *Tempering.*—Tempering means heating a steel (however previously hardened) to a temperature not exceeding its carbon change point with the object of reducing the hardness or increasing the toughness to a greater or lesser degree. This operation may usually be followed either by slow cooling or water-quenching without materially affecting the final result.

5. *Cementing.*—Cementing means heating a steel above its normalising temperature in contact with a medium which causes carbon to penetrate.

6. *Refining.*—Refining means re-heating a steel to its normalising temperature, and is usually followed by quenching.

7. *Maximum Tensile Stress.*—The maximum tensile stress is the greatest load sustained at any time by the loaded test piece, expressed in tons per square inch on the original area of the test piece.

8. *Yield Ratio or Elastic Ratio.*—The yield ratio or elastic ratio is the ratio between the yield stress * and the maximum tensile stress.

9. *Elongation.*—The elongation per cent. is the difference between the original and the fractured gauge length, expressed as a percentage of the original gauge length of the test piece.

10. *Reduction of Area.*—The reduction of area per cent. is the difference between the original and fractured areas expressed as a percentage of the original area of the test piece.

11. *Core.*—The core of a casehardened bar is the interior portion of the bar which is substantially unaffected in composition by the cementing process.

Tensile Tests.

Tensile tests usually are made to ascertain (1) the yield point; (2) ultimate stress; (3) elongation per cent.; (4) reduction of area per cent.; and in special cases load extension diagrams may be taken. These tests are all defined in the previous paragraphs, and it is not proposed, therefore, to make any further observations. The size of test pieces is now generally made to recognised standards.

* The yield stress (or yield point) is the load per square inch, at which distinctly visible increase occurs in the distance between the gauge points on the test piece, observed by using dividers; or at which when the load is increased at a moderately fast rate there is a distinct drop of the testing machine lever, or, in hydraulic machines, of the gauge finger.

The " centre pop " marks should be accurately placed, and a small jig for doing this accurately and expeditiously is shown in fig. 30.

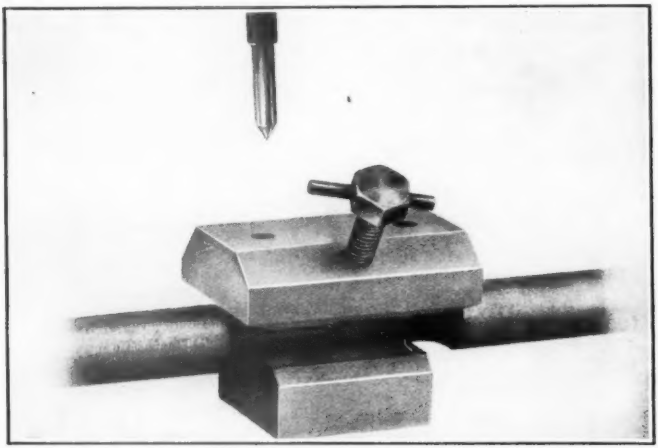


Fig. 30.—A small jig for accurately placing centre pops.

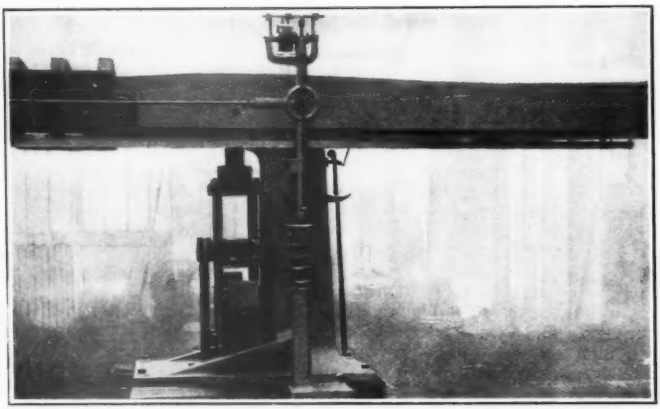


Fig. 31.—An efficient type of tensile testing machine.

The subject of testing machines is outside the scope of this paper, but one of the types in general use is illustrated in fig. 31.

Hardness Test.

Hardness may be defined as a state of rigidness in a metal which imparts to it the power to resist penetration and necessarily also deformation.

There are three types of hardness tests in use to-day: The Brinell test; the scleroscope test; and the Rudge-Whitworth file test.

LOAD OF 3000 KILOS ON BALL 10 M.M. DIAM. TENSILE STRENGTH·BRINELL FIGURE × FACTOR

A. FOR MOST STEELS WHETHER CARBON OR ALLOY HEAT TREATED IN RELATIVELY SMALL MASSES THE PROBABLE TENSILE STRENGTH WILL FALL WITHIN THE FIGURES GIVEN BY FACTORS ·21 AND ·23

B. WITH CARBON STEELS AND CERTAIN ALLOY STEELS, ANNEALED TO GIVE A LOW YIELD RATIO THE PROBABLE TENSILE STRENGTH WILL FALL WITHIN THE FIGURES GIVEN BY FACTORS ·23 & ·25

C. WHEN THE PHYSICAL CONDITION OF THE STEEL IS NOT KNOWN AND CANNOT BE DEDUCED USE RANGE BETWEEN FACTORS ·21 & ·23 FOR NUMBERS OVER 175 & BETWEEN ·23 & ·25 FOR NUMBERS BELOW 175

Impress diam. in MM.	Brinell Hard-ness No.	Equivalent Tons /□" with factor ·21	·23	·25	Impress diam. in MM.	Brinell Hard-ness No.	Equivalent Tons /□" with factor ·21	·23	25	Impress diam in MM.	Brinell Hard-ness No.	Equivalent Tons /□" with factor ·21	23	25
2 40	653	137	150	163	3·05	401	84	92	100	3 70	269	56	62	67
2 45	627	132	144	157	3 10	388	81	89	97	3 75	262	55	60	66
2 50	601	126	138	151	3·15	375	79	86	94	3 80	255	53	59	64
2 55	578	121	133	145	3·20	363	76	83	91	3 85	248	52	57	62
2·60	555	116	128	139	3 25	352	74	81	88	3 90	241	50	55	60
2 65	534	112	123	134	3 30	341	71	78	85	3 95	235	49	54	59
2·70	514	108	118	129	3·35	331	69	76	83	4 00	229	48	53	57
2·75	495	104	114	124	3·40	321	67	74	80	4·05	223	47	51	56
2 80	477	100	110	119	3·45	311	65	72	78	4·10	217	45	50	54
2·85	461	97	106	115	3·50	302	63	69	76	4·15	212	44	49	53
2·90	444	93	102	111	3·55	293	61	67	73	4·20	207	43	48	52
2·95	429	90	99	107	3·60	285	60	66	71	4·25	201	42	46	50
3·00	415	87	95	104	3·65	277	58	64	69	4·30	197	41	45	49
4·35	192	40	44	48	5·30	126	26	29	31·5	6 25	87	18	20	22
4·40	187	39	43	47	5·35	123	25·5	28·5	31	6·30	85·5	18	19·5	21·5
4·45	183	38	42	46	5·40	121	25	28	30·5	6 35	84	17 5	19·5	21
4·50	179	37	41	45	5·45	118	24·5	27	29·5	6·40	82·5	17	19	21
4·55	174	36	40	44	5·50	116	24	26·5	29	6·45	81	17	18 5	20·5
4·60	170	35	39	43	5·55	114	24	26	28·5	6·50	80	16·5	18·5	20
4·65	167	35	38	42	5·60	111	23	25·5	28	6·55	78	16·5	18	19·5
4·70	163	34	37	41	5·65	109	23	25	27·5	6·60	77	16	17 5	19·5
4·75	159	33	36 5	40	5·70	107	22·5	24·5	27	6·65	75	15·5	17 5	19
4·80	156	32·5	36	39	5·75	105	22	24	26·5	6·70	74	15·5	17	18·5
4·85	152	32	35	38	5·80	103	21·5	23·5	26	6·75	73	15	17	18·5
4·90	149	31	34	37·5	5·85	101	21	23	25·5	6·80	72	15	16·5	18
4·95	146	30·5	33·5	36·5	5·90	99	20·5	23	25	6·85	70	14·5	16	17·5
5·00	143	30	33	36	5·95	97	20	22·5	24·5	6·90	69	14·5	16	17·5
5·05	140	29	32	35	6·00	95·5	20	22	24	6·95	68	14	15·5	17
5·10	137	28·5	31·5	34·5	6·05	94	19·5	21·5	23·5	7·00	67	14	15·5	17
5·15	134	28	31	33·5	6·10	92	19	21	23					
5·20	131	27·5	30	33	6·15	90	19	20·5	22·5					
5·25	128	26·5	29·5	32	6·20	89	18·5	20·5	22·5					

Fig. 32.—Chart showing relationship between Brinell No. and maximum stress in tension.

The Brinell Test.

The Brinell test is a method for determining the hardness of the metal. It serves also as a definite measure of hardness for use in the comparison of parts after heat treatment. The indentation is formed by a hardened steel ball of 10mm. diameter pressed into

the surface of the object under test. In the formula P is the load, D the diameter of the ball, and *d* that of the ball impression, and the hardness number (H) is expressed:

$$H = \frac{P}{\frac{\pi D}{2}(D - \sqrt{D^2 - d^2})}$$

The machine is so well known that it is not proposed to describe it in these notes.

The most important use of the Brinell test is to check the heat treatment of forgings, for there exists a more or less definite relation between Brinell hardness and maximum stress in tension, as shown in the table in fig. 32.

In fig. 33 is given a table of the results of some actual tests. The tensile figures are given in tons per square inch, and it can

Tensile Test.				Impact Test.		
Yield-point.	Ultimate.	Elongation.	Reduction of Area.	Stanton 2in. blows.	Izod. ft. lb.	Brinell.
		per cent.	per cent.			
55·6	69·56	14	52	9,528	29	364
51·56	70·64	13	46	7,917	29	351
60·32	69·6	14	52	10,514	28	351
52·36	73·92	13	47·25	8,612	29	345
62·6	77·04	11	48·8	7,413	15	410
64·28	75·8	10·5	38·4	8,000	16	418
73·32	85·4	13	47·2	9,001	14	418
64·0	75·6	11	43·25	7,598	17	402
63·0	73·8	12	46	8,620	16	402
70·0	82·0	14	47·28	8,333	13	402

Fig. 33.—Table of test results showing relation between impact and tensile values and the Brinell No.

readily be seen from the figures how the tensile and impact values vary with the Brinell hardness. In some cases it is not possible to use the standard load of 3,000 kilogrammes, and if the load be varied it is important that the necessary correction be made.

The Brinell test should not be made upon the skin of a heat-treated forging or stamping, so that this skin should be removed either by wet grinding or by filing. The Brinell result which would be obtained from the surface will differ from that which is obtained from the machined stamping owing partly to the fact that the skin of the forging has been decarbonised during heat-treatment.

For a steel of given analysis the Brinell hardness number of a piece of heat-treated steel varies with the ultimate tensile stress obtainable, but the Brinell value obtained from a piece of steel in condition "as rolled" or "as stamped" is untrustworthy, as the hardness of the surface of the steel may be affected by the amount of work which is done on it as its temperature decreases in the rolls or during the forging process.

For carbon steels the Brinell result on a piece of steel "as stamped" may in some cases be the same as the Brinell result which would be obtained upon a piece of steel in a satisfactory heat-treated condition. Hence the Brinell test is of little value when used on a carbon steel for detecting stampings or forgings which have not been normalised or heat-treated.

Test pieces for mechanical tests should be heat-treated with each batch of stampings, and, in addition to the tensile and impact tests called for in the specification, Brinell tests should be made upon these pieces. If the tensile and impact tests are satisfactory, the Brinell value is used for checking the stampings heat-treated with the test piece. Provided that the test piece and stampings have been heat-treated at the same time, and are of the same material, it may be assumed that the tensile strength of the material in the stamping bears the same ratio to the tensile strength obtained on the test piece as the Brinell hardness number on the stampings bears to the Brinell hardness number on the test piece. Using this relation it will be possible to work out approximately the ultimate tensile strength of the stampings. If the tensile strength calculated in this manner satisfies the specification, the stampings may be passed.

The Use of the Scleroscope.

The scleroscope is intended primarily for the testing of the hardness of surfaces by comparison with a standard, and the results of such testing cannot be taken as any indication of the tensile strength of the material. Its use, therefore, is restricted to the determination of degrees of hardness only between parts of the same design when manufactured from material of the same chemical analysis—within close limits.

Use.—The following precautions must always be taken in using the instrument:—

(*a*) It is most essential that each instrument should be used under identical conditions, particularly with regard to support and lighting. It is preferable that the instrument should be mounted on an iron base such as a surface plate; different readings can be obtained when artificial instead of daylight illumination is used.

(*b*) The surface of the article to be tested must be polished and smooth, but different methods of polishing may give different results.

(*c*) If the surface of the article to be tested is round, such article must be rigidly supported with the axis of the curvature directly under the centre line of the instrument.

(*d*) The mean should be taken of three or four readings in the same vicinity; care must be exercised to take each reading in a different place, as the indentation caused by the falling weight affects the hardness locally.

Calibration of Instruments.—Standards or figures established on one instrument do not necessarily hold good with another instrument. It is desirable, however, that where two or more instruments are used these should be checked against one another for the purpose of establishing standard reference numbers for various parts.

Casehardened Material.—In order to establish the standard for an article in any given casehardened material, correctly heat-treated samples must be tested by means of a file or subjected to some approved scratch test, which sample should be marked and retained as the standard of reference for that particular part.

THE HARDNESS AND STRENGTH OF STEEL.

COMPARISON OF BRINELL BALL AND SCLEROSCOPE HARDNESS NUMBERS WITH THE COMPRESSION STRENGTH YIELD POINT AND TENACITY OF STEEL.

Zones of Hardness. *F* to *A*.	Approximate Scleroscope Hardness Number.	Brinell Ball Hardness Number.	Tensile Strength.				Compression.		
			Yield Point.		Maximum Stress.		On specimens 0·564in. diameter and 0·70in. in height.		
							Elastic Limit.		Compression per cent.
			Tons per sq. in.	Kilos. per sq. mm.	Tons per sq. in.	Kilos. per sq. mm.	Tons per sq. in.	Kilos. per sq. mm.	(100 tons per sq. in. 160 kilos. per sq. mm.)
F		150	20	31	36	57	17	27	49·0
		175	26	41	41	65	19	30	40·0
	34	200	32	50	46	72	21	32	35·0
E	38	225	38	60	51	80	23	36	31·0
	42	250	44	69	56	88	26	41	27·0
	46	275	50	79	61	96	30	47	23·0
	50	300	56	88	66	104	34	54	19·0
D	54	325	61	96	71	112	38	60	15·2
	57	350	67	105	76	120	43	68	11·3
	61	375	73	115	81	128	49	77	8·0
	64	400	79	124	86	135	55	87	5·6
C	68	425	84	132	91	143	61	96	3·8
	71	450	90	142	96	151	67	105	2·4
	75	475	96	151	101	159	74	116	1·3
	78	500	102	161	106	167	81	127	0·6
B	80	525	107	169	111	175	87	137	0·23
	84	550	113	178	116	183	94	148	0·21
	86	575	—	—	121	190	101	159	0·20
	89	600	—	—	126	198	108	170	0·18
A	92	625*	Not determined.		131	206	115	181	0·16
	95	650			136	214	122	192	0·14
	99	675			141	222	129	203	0·13
	101	700			—	—	136	214	0·12
A 2. Owing to want of data but little is known about this extremely high zone of "super-hardness" ..		725	Not determined.		Not determined.		144	227	0·11
		750					151	238	0·09
		785					159	250	0·08
		800					166	261	0·07

* Glass scratching hardness commences here.

Fig. 34.—A comparison of Brinell ball and scleroscope hardness numbers.

THE HARDNESS AND STRENGTH OF STEEL.

THE CAPITAL LETTERS IN THE ZONE COLUMN REFER TO THE FOLLOWING ZONES OF HARDNESS

Zone.	Brinell Ball Hardness Number.		Scleroscope Hardness Number.		Yield Point. Tons per sq. in.		Maximum Stress. Tons per sq. in.	
	From	*To*	*From*	*To*	*From*	*To*	*From*	*To*
F	150	200	—	34	20	32	36	46
E	200	300	34	50	32	56	46	66
D	300	400	50	64	56	79	66	86
C	400	500	64	78	79	102	86	106
B	500	600	78	89	102	Not determined.	106	126
A	600	700	89	101	Not determined.	„ „	126	Not determined

Fig. 34.—*Continued.*

Fig. 34.—A comparison of Brinell ball and scleroscope hardness numbers.

The hardness number obtained by each individual scleroscope is established from this standard, and a tolerance of up to +10 or −10 is permitted, according to the nature of the material and the duty of the part in question.

The condition of the core of casehardened parts may affect the reading obtained, and it is therefore essential that each batch of parts tested should have been previously approved on fracture tests.

The following figures may be taken as a guide to the hardness number and the tolerance which may be expected from the following grades of steel :—

Carbon casehardened steel ... . 80+ 5−10.
3 per cent. nickel casehardened steel ... 70+10− 5.
5 per cent. „ „ „ ... 60+10− 5.

Sheet Material.—Scleroscopes may be employed for testing the hardness of rolled sheet material used for special purposes, such as for springs, etc., where the degree of hardness is important. The object of such testing is to augment other tests to ensure that the condition of the material is consistent, and any scleroscope number established for such material must be based on an actual test on a sample of approved material which should be retained as the standard.

The author is not aware of any established relationship between the hardness values of steel obtained by the scleroscope and the Brinell tests, and it is generally considered that there does not exist any reliable relationship between the two. It may be of interest, however, to present a chart of comparisons, which are shown in the table in fig. 34. The figures given in this table are not submitted as authoritative data, but the figures may be of use in cases where it is desirable to have some idea of the kind of relation which may exist between these tests.

Notched Bar Tests.

A great uncertainty has prevailed as to the meaning and value of the notched bar test. It is often stated that it indicates nothing which cannot be deduced from the results of the ordinary tension and other physical tests.

The failure in materials used in high-speed machinery under repeated forces of an impulsive character, even when such material has shown satisfactory strength in the static tensile test, has led to many

attempts to devise a shock or impact test which would discover the imperfection in material likely to fracture by shock.

It is not necessary, however, to argue in favour of the notched bar test, for it has become firmly established. It is interesting to note that this test was standardised by the German Association for Testing Materials as far back as 1907.

As the result of several separate investigations it is now generally agreed that the notched bar test definitely reveals something in steel which is not disclosed by any other test. The notched bar test undoubtedly reveals a bad physical condition which could be produced in certain steels by methods of heat treatment, and in such cases no other testing methods are known which would indicate such an imperfect physical condition.

Philpot, in his paper,* gives some experiments of notched bars, and, as the result of very excellent work, arrives at some very definite conclusions. Considering this work, together with that of other investigators, it is now generally accepted that :

1. The tensile test, even when an extensometer is used, does not give any satisfactory criterion for detecting the condition of the material which gives low values in the notched bar tests.

2. A dangerous type of brittleness occurs to a greater or lesser extent in all nickel chrome steel which is not revealed by the ordinary tension tests, but is revealed by the notched bar test.

There are several types of notched bar testing machines working on a similar principle, the chief of which are :—

(*a*) The Izod pendulum type.
(*b*) Charpy pendulum type.
(*c*) Frémont falling tup.

In the table below data are given of some of these machines.

Type of machine.	Striking energy kg.m.	Striking velocity m. per second.
Charpy, pendulum .. .	30	5·3
Izod, pendulum	16·6	3·5
Frémont, falling tup	20 or 60	8·85
Amsler, pendulum	30	4·95
Guillery, rotary flywheel ..	60	8·85

The machine of this type in the most common use is the Izod type, shown in fig. 35. It is not proposed here to describe this machine. It is important, however, to mention that the results obtained are dependent to a very large extent on the radius of the bottom of the vee notch. This radius must be exact, otherwise very curious results will be obtained, and no definite information is yet available which permits of comparison between the results obtained from specimens of different radii of the bottom of the vee notch.

* "Some Experiments on Notched Bars." By Captain H. P. Philpot. Proceedings of the Institution of Automobile Engineers, Vol. XII, p. 235.

Nor is there any definite comparison between the results obtained from test pieces of various sizes.

It is impossible to compare two steels such as a plain carbon steel and a nickel chrome steel upon the basis of absolute Izod values obtained from them. If such comparisons were made, the conclusions would be entirely wrong in many cases. The notched bar values obtained from a steel must be evaluated after taking into account the type of steel on which the result was obtained.

Usually as the tensile strength increases the notched bar value falls. This is usually provided for in the specification.

There are many other kinds of physical tests carried out in the ordinary process of material inspection in many works, but to enter into the details of all these tests is beyond the scope of this paper. The author has purposely dealt with those tests which are in use generally in the majority of engineering works to-day, and

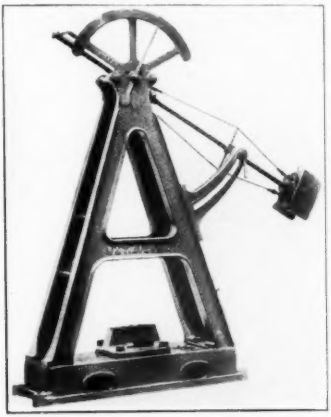


Fig. 35.—The Izod impact testing machine.

the tests given in these notes usually form part of an inspector's ordinary duties.

Conclusion.

It is realised that these notes are very far from being complete—and without making them voluminous, it has only been possible to touch on a few of the problems arising out of workshop inspection.

As, however, inspection is now one of the most important departments in a works organisation, it is hoped that the author's remarks may serve a useful purpose by solving many of the problems which the inspector has to face.

It is also hoped that the information given may be of interest to those who desire to have a fuller knowledge of the work of an inspector, and will help to emphasise the importance of the inspection department.

THE DISCUSSION.

MR. BUTLER (Member of Council) in opening the discussion said that inspection of materials, or inspection generally, was a very large subject. The inspection of raw materials was one of the most important parts of inspection work, because, after all, if they got bad or unsuitable material into the shops they laid themselves open to waste a lot of money and time through working on material which was totally unsuitable for the job. In a number of factories at the present time there was not sufficient attention paid to raw material inspection. He had been very pleased to note the arrangement of the view room in fig. 1 in the paper, and it was important that when they laid out a factory and started a system, or re-organised it, with any intention of carrying out a proper inspection procedure, they should get the view room and the departments connected with it as nearly central as possible. The question of whether the system of floor viewing should be adopted, or that of taking the parts to the view room for inspection, or a combination of the two systems, depended upon the class of work carried out. If the work was big and a number of operations were involved, floor viewing was the only feasible plan. For physical tests, of course, the articles had to be taken to a special department, because they could not have an Izod machine, etc., in a machine shop, but these tests are usually made before machining operations are commenced. For small parts, especially when produced on automatic machines, it would save a lot of time if these were taken to a view room, and a different class of inspector could be employed in the view room. One who was engaged all day, possibly, on straightforward operations working to limit gauges could be a semi-skilled man at a lower rate than a floor viewer in a machine shop, who had to be capable of taking on almost any job from almost any machine. In the methods outlined in the paper the clerical work seemed somewhat elaborate; the tendency at the present time, when we were trying to get down to competitive lines, was to knock out as much clerical work as possible. It was more or less all an overhead charge, and it seemed to him that if there were too many forms and cards to be filled up, the foreman or charge-hand in a department was mostly employed looking after paper instead of production. In the majority of work, unless it was very important work, it was totally unnecessary to give particulars of physical tests or analyses of materials on the back of any card in the works; that had to do with the laboratory or the chemistry department. A specification number might be quoted, but he did not think anything else would be necessary for the average viewer, at any rate in the ordinary factory. The bonus ticket, of course, they must have where there was a bonus system or a piecework system, but the less paper they had in a shop, outside the ordinary bonus ticket and some simple form of progress ticket, the more time they would allow the foreman to give to the accuracy and actual pro-

duction of the work. With regard to drawings, the question of limits was always an open one. He was of opinion that they had to be guided very largely by the notation of the limits that were being carried on in the particular firm. If they changed their system of notation of limits in a factory because one or two men knew one system better than another, the inconvenience caused for some time by that change was generally more than the advantage gained by the alteration, even if the new system were the better. He did not see any objection, where they were working to gauges and drawings, to stating the limit that they were working to in exact sizes and decimal sizes. If it were 1½in. minus nothing plus three-thousandths, he did not think it was necessary to put down three sizes; they were only dealing with two, 1.500in. and 1.503in.; the gauge could be marked in decimals and they could always pick up that gauge and the sizes were definitely on it. If they took the nominal size they might easily get hold of a gauge belonging to another job with the same nominal size, but with a different limit. They did not always get the drawings and refer to them as they should do. When a piece had been produced in a shop week after week, and perhaps month after month, a man would see that the drawing number was so-and-so, would know that the gauges were in the drawer, and would go on using them. That was not an ideal method of working, but it was very largely done. With regard to physical tests, the majority of firms had to rely pretty well on the maker's specification or on the purchasing department ordering the material to specification, and taking due precautions, by having a piece tested occasionally at a laboratory, to see that the specification was upheld, but he did not think there were many firms, unless they were on large production work, that could afford to lay down the necessary testing apparatus and engage the necessary staff to take physical tests properly and sufficiently often to make sure that everything was all right. After all, if they had a batch of steel they might test one bar or the end of each bar. If they did that, and it was the only way to find out whether the material was really up to specification, it was a big job and would add considerably to the cost. Some of the motor-car work might stand it, but a lot of the smaller accessories would not. If they ordered to specification, the manufacturers with any reputation at all could be relied on to keep it up pretty well. It is quite a simple matter where the material has to be heat-treated to take a test piece from each bar of material used on important work, and after heat-treatment to observe the fracture; the information to be obtained by this method is very reliable, and does not necessitate any additional equipment.

Mr. Hales agreed with Mr. Butler in certain of his remarks, inasmuch as the method described in the paper would appear to be over-elaborated, except in the case of an extensive works dealing with large quantities of parts, particularly with regard to duplicating time-cards, slips, and scrap records.

It should be sufficient for the information shown on the slip illustrated to be given on the back of the time card, to be immediately passed to the progress department, and from thence to the cost department, whose function makes it necessary for them to further record the information *re* quantities produced, "good, usable, scrap, etc." It would therefore appear advantageous for the cost department to issue duplicate records, when the *cost* extension could be

shown against them. He could not agree with inspectors spending the necessary time to fill up duplicate forms.

The forms shown, generally, were very good, particularly those relating to materials. Some very useful information was given which would be a guide to designers when laying out work. There was one other point in the paper, however, with which he could not agree; he had understood Mr. Fairbrother to say that it should be the duty of the inspection department to set out the limits on the drawings. He thought that was outside their functions altogether.

In the first place, it was absolutely essential that all dimensions, limits, etc., should be definitely fixed before the work got to the inspection department. To his mind, the dimensions and limits should be determined by a competent man in the drawing office, in conjunction with the production engineer or processing and layout department, who were more in touch with the works operations.

It was preferable to decide any points relating to drawings when the layout of operations was made and the bonus times fixed before they got near the inspection department, because unless they were fixed before actual manufacture it was possible that there might be a lot of jigs, tools, and gauges scrapped. The inspection department did not get the work, and therefore could not check it until the work came through, and prior to that date all the gauges, jigs, etc., would be made.

The chief objection to an over-elaborate system in any section of manufacture was the tendency for the department concerned to overlap the *real* function of other departments in the works, which should be most carefully avoided.

Mr. Bell said there were one or two points raised in the paper which had very much impressed him, and he believed that a consideration of them had not been seriously undertaken by most of them. During the war many of them were extremely annoyed and harassed by a certain very important inspection department, and most of those concerned with production had thought at the time that many of the points which were raised and many of the laws laid down during that period were unnecessarily harsh. Since the war he had had an opportunity of going into many of the points which were raised, and he agreed with them now, although during the war he did not. As to an inspection department, he believed that in the discussion on practically every paper before the Institution he had expressed the view that the scheme laid out was much too complicated. That became a comparative term. The scheme outlined in Mr. Fairbrother's paper would be complicated for a small works, but for a very large works, where the capital was available and where the output was of such an order that the capital outlay on such a department was allowable, it was not too great. It became a question of degree with every works. The investigations carried out during the war by the Government inspection departments were of a very close nature, and of an order that no private firm would possibly have carried out. Each firm was more or less a closed room, but under that particular Government Department the results which were obtained in the various firms were collated, and the resulting information was of very much greater value in consequence. He had come to the conclusion that it was a very great pity that the information which was collected during the war by that department should not have been more widely distributed;

its enormous value was not yet appreciated. As to whether floor-viewing should be adopted or a view room used, it was a question of adopting a system in accordance with the particular type of product on which a works was engaged. Some work could be best viewed on the floor, and other work must necessarily go into the view room; to dogmatise and say that all products should be viewed on the floor or in the view room would be wrong, and they would be creating tremendous difficulties which were unnecessary. Adaptability was the great point. They could not go from one works to another and take a system which had been used in one works and plant it straight into another and expect it to operate readily. A system which was successful in one works needed a fair amount of alteration before it could be properly adapted to run in another works, and the measure of success attained by the manager would depend, in his opinion, very largely on the measure of his adaptability. With regard to the plant suggested in the paper, very few works could afford to put down such a plant. He did not think there was any doubt as to the value of the information gained, and it would almost suggest that such a Government Department as existed during the war would be very valuable, even in these days of the "axe," to collect information and distribute it. He did not think it possible for any firm to collect that information, but even if it did it would never be distributed for the benefit of the country; in this Government Department the information was really for the benefit of the country. It would be of enormous value, and it was a point which would bear very serious consideration. In private works there would never be the time or the capital for it. It was as much as most of them could do to carry on with ordinary production, apart from carrying out investigations. A very close study of the information which was available from the work carried out during the war, would benefit those firms which had not been able to carry out such investigations privately, and all those concerned with production would benefit very much by it. He personally thanked Mr. Fairbrother for his paper. He did not know of any paper bearing on the subject which had been so comprehensive or which dealt with the subject with such minuteness.

THE PRESIDENT said that the author had, in fig. 14, admirably illustrated five different ways of figuring out tolerances. A great many people dropped into errors, and taxed themselves largely in money, by not realising exactly what they were doing when fixing their tolerances. It was a mistake to use the bilateral system, and anybody who had the opportunity to change to the unilateral system would save themselves a vast amount of money and trouble. The great disadvantage in the bilateral system, *i.e.*, adopting plus and minus tolerances, was that no dimension could be read without a calculation. That meant that every one of their operators had to do a sum in arithmetic before he could use any dimension on a drawing, and every time a piece was made a firm had to pay a man to do that calculation, which, even if it only amounted to a matter of seconds, added up to a good round sum. Then the calculators were not always competent, and they made mistakes, and he had had a lot of scrap through people making calculations wrongly. They would take a plus for a minus, or a minus for a plus, and so cause waste. Fig. 15 in the paper was a chart of the screw thread tolerances recommended by the British Engineering

Standards Association, and it had always appeared surprising to him that these recommendations could have been made in sizes below 1¼in. In the chart they gave a maximum clearance between nut and bolt of 12/1,000ths of an inch on a ½in. bolt. The thread was not very much deeper than that, and if they had a nut and bolt of ½in. diameter, of 20 threads per inch, in their hands, they could almost pull the nut off; it was really astonishing. In 1910 he went into the matter of tolerances on a screw thread, and tried to specify a commercial tolerance that would satisfy him when building motor cars with those fine threads, and to realise the tolerances shown in the table was absolutely hopeless for their purpose. They got a ½in. 20-thread nut, and if there was 2/1,000ths difference between that and the bolt it was as loose as anybody would pass, and it was liable to break loose. Anybody adopting the chart ought to try the maximum fits before they bought to that specification, otherwise they would rue it, as he had done. He had wasted a lot of money over it, and when it came to specifying something that would allow him to purchase bolts and nuts at a reasonable price he gave it up as a bad job, and the method he adopted was to specify the fit, and that did not interfere with the price. Any nut and bolt manufacturer would give them spanner-tight nuts and bolts all the time, and if they tied him to one dimension—and he believed that was the reason why the outside diameter for the screw thread was specified—they got a very satisfactory job. Whilst it was very nice to have these beautiful devices for measuring pitch, angle and thread, etc., it was not necessary in commercial nuts and bolts. Another thought in dealing with inspection was that inspection would not be necessary or desirable if nobody made mistakes; production engineering did not mean to elaborate or expend more energy in inspecting work after it was done, but to elaborate making it correctly, which was the most economical aspect from which to tackle the problem.

Mr. Lambert said that in the early part of the paper the author had remarked that floor inspection would probably increase the staff of the progress department. That was rather a debatable point, because, whether the work was inspected in the shop or in the view room, the progress staff could follow the work through as easily in the shop as they could in the view room. Speaking of the floor inspection and view-room methods, some of the chief conditions which governed the method adopted were the class of work carried out, the size of component parts, and the capabilities of the staff. There is no doubt that for floor inspection a more capable man is required than for the view-room method. There was an old saying in the workshops, which may have a certain amount of truth in it, that anybody could inspect a job, but it took a mechanic to make it. When inspecting work in the shops the inspector should know his job thoroughly, *i.e.*, he should be thoroughly conversant with the work he is inspecting, and it would well pay some of the larger firms if they spent some time and trouble in giving tuition to the inspection staff where the floor-inspection system was adopted, because the man inspecting the work in the shop ought to go a little further than trying up dimensions, etc. He should know what the subsequent operations were, what the job is for, its functions and so forth. With regard to the checking of screw-ring gauges, Mr. Lambert said he was not quite clear from the slide illustrating the plug gauge for checking ring gauges for sparking plugs on one point,

and that was that if the thread in the ring gauge was cut on the deep side, how the plug gauge illustrated was going to find out that error. If a thread in a ring gauge is cut too deep, it is possible to pass components which are oversize on the top diameter of the thread, and this error would probably prevent it entering the female component. In his experience, where thread gauges had to be accurate to fine limits it was advisable to make up a plug gauge with a thin thread and oversize on the top diameter to check the female gauge for depth of thread. Also, in checking the effective diameter it was advisable to have a double-ended thread gauge made up, one end plus on the effective and the other end the correct size, to make quite sure that the female thread was not plus on the effective diameter.

MR. LEE said there was no getting away from the importance of inspection, because the whole reputation of a firm depended on the goods it made, and inspection was the means whereby quality could be ensured. Therefore, inspection should begin with the raw material and should go right along to the finished product. He agreed that the system outlined in the paper was too elaborate for a moderate or a small firm, and only suitable for a firm of large proportions. There was one instance mentioned by the author where a card in triplicate was taken by a skilled man to a clocking clerk to be stamped. It seemed to him that that man's time would be better spent if he kept at his machine. With some systems in America it was a crime for a man to leave his machine, and if he wanted a card stamped he had to give it to a lad or a runner employed for the purpose. Again, it afforded a good opportunity for a chat between the clock clerk and the skilled man. Nothing had been said as to the internal organisation of the inspection staff themselves; for instance, how instructions were given to the unskilled man, whether he would get advice from the chief inspector or whether it should be written down on paper for him.

MR. FAIRBROTHER, replying to the discussion, dealt first with the suggestions that the system was too elaborate. When one examined the system very carefully it would be found that the viewer made out two cards and filled in another one. Someone had to do it, because records must be kept of what went on in the factory. As to the foreman doing clerical work, he had mentioned in the paper that it was very essential that the foreman should not be made into a "glorified clerk." Records must be kept if a factory was to be run efficiently, and he could conceive of no other department better able to do this than the inspection department. The system he had described was working efficiently and the costs were not very great. He had not described a system for any particular factory; obviously, if the factory was small the inspector might be eliminated and the work done by the foreman, but if the works were large they must have inspection. The author drew attention to the following passage in the paper: "An inspection department may be paradoxically described as a necessary luxury. Theoretically, it should not be necessary, as operators are paid to produce parts in accordance with instructions. Practically, it is found necessary, for the simple reason that it is impossible to eliminate the human element." Several speakers had referred to the merits of floor viewing and centralised viewing. In the paper he had said that either system might be economically employed. There was no doubt that floor viewing was useful, and might be economically applied where each department was self-contained; but where they had one machine shop, with the

machines set out in groups, if floor viewing be adopted the article had to be inspected in a particular department, then had to go to another department—which might be at the other end of the shop—for the next operation. The progress man had to take it to the next department. If the work were passed through the view room, all the work from various sections was bunched together, and the progress department was cut down by means of a centralised view room. The progress man would take a truckload of parts from the view room to a particular department for further operation. As the works production was usually somewhat ahead of the viewing department, they could afford that small amount of time to allow the parts to accumulate. He agreed with Mr. Butler that a foreman should not have clerical work to do; his aim in life was to get quantity with quality, and he had to see that every machine and every man in his department were usefully employed. As to Mr. Butler's remark that where a man was doing a particular job day in and day out he would go to a drawer and find his gauge; there was no guarantee that that gauge would always measure the same, and it should be made clear that at least once a week the gauges should be thoroughly inspected. Regarding physical tests, he had described a system which might appear elaborate, but that physical test department served the purpose of checking the material coming into the factory, which was important when manufacturing an important article. We must make progress, and he was afraid that we were somewhat backward in this country. Take the notched-bar test, for instance. The Germans had adopted that test in 1907, and we were only just beginning to realise its importance. To make progress we must investigate, and that was part and parcel of the work in the inspection department. An inspector should be *au fait* with all that went on in a factory in connection with the materials he was using, and if the chief inspector were conversant with what was happening concerning the investigation of defects, he could use his own discretion in preventing the repetition of any trouble. Physical tests entirely depended on the class of work carried out; in some shops it might not be necessary. Mr. Hales had referred to limits on drawings. He (the author) had never suggested that the inspector should fix the limits. What he did suggest was that the inspector should have something to say about the fixing of the limits, and he did not say that the drawings should go into the works without being fixed. Obviously, the limits must be put on in the drawing office, but where they had a competent chief inspector, with the parts passing through his hands continually and one who knew exactly what the shops could do and to what limits the machines were capable of producing, he should have something to do with it; but the drawing office should put the limits on the drawing. He (the author) mentioned a case of an aluminium casting where the expansion of the casting in the machine had absorbed the total tolerances, and held that a chief inspector was a man competent to talk of limits; he should be consulted before the drawings were finally approved, although the machine-shop superintendent could do it if he had time. It was no use having watertight compartments in any factory nowadays. Mr. Bell had pointed out that the knowledge collected by the Government Inspection Department during the war should be made public; he agreed. Very few people realised the value of the information that had been obtained. There was much knowledge lying dormant which would be very beneficial at the

present time. As to tolerances, the author preferred the unilateral system, as did the president. He had said in the paper that there was a bias to-day in favour of the unilateral system, but as a committee had been considering the question for six years and had not reached a decision, he did not think he was competent to do so. He believed that before long the unilateral system would be adopted. As a matter of fact, the German Standardisation Committee had already adopted it, and we should be behind them once more; they were going ahead with it at the present time, whereas we had not made up our minds. A decision on that point would be of very great use. The president had also mentioned commercial screw threads. It was all very well to say that if a screw thread was spanner-tight it was satisfactory; but he did not think it was until they found out what element made for tightness. It was essential that steps should be taken to ascertain what was causing tightness. As to spanner-tight nuts and bolts, he suggested that those interested should read Strohmeyer's paper given before the Institution of Naval Architects, March 21st, 1918, on "Stress Distribution in Bolts and Nuts," which was very instructive in connection with stresses in screw threads. Regarding the remark that anybody could inspect an article, but that it took a mechanic to make it, there might be some truth in that; but he felt that if people in the works were still going about decrying the inspection department, some good inspector should get hold of them and educate them as to what he was and what he could do. An inspector to-day had knowledge. He admitted that during the war, owing to the shortness of labour, people were employed who could not have been efficient inspectors, but they did specialised work satistorily, and probably could not do a job in the works. To-day, however, inspectors were mechanics; in fact, the majority he came across could actually do the job in the shop. They would get good inspectors when firms realised the importance of an inspector, asked for good men, and paid them adequate remuneration for the work they were asked to do. He had purposely left out anything about screw gauges, but his method of inspecting the bottom of a ring gauge, which he had found most satisfactory, was to make a plaster of paris cast of the gauge, throw it on the screen, against the theoretical size, drawn out fifty times full size, and then he could find out which element was in error. It did not take long, and it saved the use of a lot of elaborate gauges. If he had omitted any points he would reply to them in writing. In conclusion, he thanked the speakers for the helpful suggestions they had put forward.

COMMUNICATIONS.

Mr. Fairbrother in his paper read before the Institution of Production Engineers on March 24th introduced, and ably dealt with, a subject that provides ample scope for discussion. A few years ago, and even at the present time in many small works, the only inspection known was the "once over" by the foreman, and a very busy foreman at that.

In such works the quality of the product depends almost entirely on the skill of the workman; and even granted that he is both skilful and conscientious, he must be well acquainted with the requirements of the work in order to be able to do justice to both his employer and the purchaser of the goods.

A high labour cost of production does not of necessity mean a well-made article; the time may be spent in machining parts which would be equally satisfactory painted, and these may not even be visible in the finished article. Cases are not unknown where surfaces have been machined for location in subsequent operations; later the operations have been revised, yet those surfaces have still been machined.

Finish, except as regards the effect on the working and wearing of the parts, is not usually the concern of the designer, but is decided in accordance with the requirements of the market in which the goods are to be sold. The inspector should see that the required standard of finish is maintained; a higher finish than this, however, will probably mean increased cost of production, whilst a lower standard will result in a lost market.

The chief inspector should be acquainted with the function of each part and the working of the complete mechanism, so that he may be able to decide whether parts not conforming to the drawings, and therefore liable to rejection, may be passed for use. Often such parts may be used without detriment, although it is not desirable, for many reasons, to give a wider tolerance on the drawing.

Co-operation and good feeling should be encouraged between the foreman and inspector. It is a mistake to imagine that the foreman is kept "up to the scratch" by an inspector when there is enmity between the two, although this theory has often been advanced.

The inspector is responsible for quality, of course, and the foreman for quantity.

With regard to floor inspection, this certainly is an advantage with large work where the machines are arranged so that the parts can be passed from machine to machine until they are completed; but where the machines are grouped, and in any case where the parts are small, centralised inspection is certainly better.

However, where large quantities of parts are being made it is an advantage to have a "travelling" inspector," whose duty it is to pass from machine to machine inspecting the work as it comes from the machine, particularly for finish, as it is better to stop bad work

at this point than to wait until the whole batch is completed on that operation and sent to the inspection department.

In his diagram of the factory arrangement in fig. 1 Mr. Fairbrother does not show provision for the inspection of the finished article. The final test should certainly be included in the work allotted to the inspection department, and should come under the same chief inspector as the component parts.

Parts are sometimes "fitted" during assembly, although particular care may have been taken to make these parts to the sizes given on the part drawings.

A case in point may be instanced where a machine had been returned for overhaul. The whole machine was dismantled and the individual parts sent to the inspection department for checking. Several of the parts were rejected and new parts drawn from stock to replace, and the whole sent to the assembly department. One of the parts was of such a curious shape that the chief inspector took the rejected part to the assembly shop foreman, who informed the inspector that all these components were made that shape before the machines left the works. Considerable trouble had been taken to keep these parts to a shape which was incorrect.

The cards shown giving a record of good parts and scrap are very useful, but sometimes these would not show the real culprit. Take, for instance, where an article is made by chucking twice and centring, afterwards being finished by grinding; if the two ends are not concentric the work will be scrap, and this will be shown on the grinder's card, although this should be obviously recorded against the inspector who passed the parts from the previous operation. (This would be covered, of course, by the reason for rejection on the view room inspection card (fig. 8), but a note should be entered on the man's card.)

A point which does not appear to have been mentioned in this paper is the periodic inspection of the gauges and tools used in the shops. These should be inspected regularly while they are in use, and not left until defective work is produced; while every gauge and tool returned to stores after use should be inspected before it is put away, so that it will be correct and ready for re-issue when required.

Special conditions sometimes govern the inspection of some parts, as, for instance, the inspection of insulations used on high-tension electrical work. Each piece must be tested after the machining operations are complete, as tests conducted when the material is in the rough state do not always eliminate faulty material.

An efficient inspection department is certainly of great assistance in any organisation, and Mr. Fairbrother has handled the matter very well in his paper.

ALBT. F. GUYLER, M.I.P.E.

Nottingham.

The ground was very well covered by the author of the paper on "Inspection Methods," and the paper shows that he has a comprehensive knowledge of the subject. Various criticisms were made in connection with the complexity of the system described, but this is naturally a question of degree, and no one system would be suitable or adaptable to every firm.

Arising from this is a point upon which the Institution of Pro-

duction Engineers could be of very great assistance to the members. If, from various members of the trade, statements were obtained relating to the proportion of labour (set out either in terms of *personnel* or in comparative labour charges) which is employed directly on inspection as compared with purely production processes, the data would be invaluable to many engineers.

The author dwelt at some length on the inspection of materials. Whilst the writer agrees that this is an all-important matter, it seems possible that the physical and chemical tests of materials in their raw state may be left to the manufacturer after calling for a certain specification.

As regards the dimensional inspection of raw material, there is a considerable opportunity for improvement on the part of suppliers, and it is essential that every stamping and casting should be properly inspected when received in its raw state. It is, however, a comparatively simple matter to reject material on these grounds, but, from the writer's experience, it is very difficult to obtain the necessary attention on the part of the suppliers to rectify or prevent the troubles that so frequently arise.

One point not touched upon by the author, but which is undoubtedly well worth considering, is inspection during assembly. With a well-organised staff on quantity production, it may not appear necessary that inspectors should be engaged on assembly work. Where, however, the human element comes into consideration, it is always possible for parts to get through to the assembly shop which may not be correct, and which would naturally cause trouble.

On the other hand, it is no uncommon occurrence to see a so-called assembler spoiling parts which have been correctly machined to drawing size, but which cannot be assembled owing to the limits being incorrect. This is almost bound to happen on new products before definite limits are obtained and verified by actual assembly. It is the duty of an inspector or investigator on the assembly side to watch these points, and, having located trouble, to report at once to the chief inspector, who will take the proper steps either to rectify the faulty parts or to get the necessary alterations made to drawing limits to prevent a recurrence. Inspection is also desirable on the completely assembled part or component to see that the part functions correctly and that the unit is constructed to schedule. These duties are at least as important as the inspection of machining operations.

A further factor in inspection efficiency which was not mentioned by the author, with the exception of its application to gear inspection, is the safeguard of inspecting first operations. More scrap is avoided and better workmanship obtained by a systematic inspection of the first of the batch than by any other method.

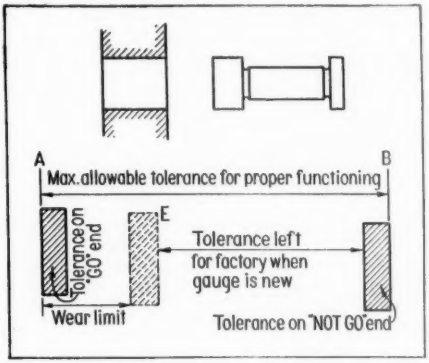
The main object of inspection is not to scrap parts which are faulty, or simply to prevent faulty parts getting into use, but as far as possible to prevent scrap work being manufactured. This is best accomplished by having the first part that is machined thoroughly examined at each operation. When this piece is approved by the viewer it provides the operator with a standard to work to, whilst if it is not correct investigation will show whether faulty tooling or carelessness on the part of the operator is the cause.

Maidstone. JOHN T. KENWORTHY.

I listened with great interest to the paper on "Inspection Methods" read before the Institution of Production Engineers by Mr. E. Fairbrother, but having to catch a train it was unfortunately impossible for me to enter into the discussion. The subject-matter of the lecture was one of paramount interest, since without proper inspection it is impossible to obtain systematic and regulated production.

It is true that during the war a large number of firms were forced to use systems of inspection which were quite new to them, but a number profited by the knowledge gained, and turned it to use by improving the manufacturing conditions of their peace-time products. The large majority, however, have reverted to their pre-war methods, in which inspection plays a very small and undignified *rôle*, being employed more on sufferance than in a genuine attempt to produce articles of a definite quality on an interchangeable basis.

The inspection department of a factory is an easy guide to the true quality of the work that is produced, and while a good machine



shop is essential, the machine tools lose much of their value and efficiency unless they are properly controlled.

In some factories where the production of parts to definite limits is in vogue it is surprising to find that the fundamental principles which underlie all gauging are not fully realised.

A large number of firms do not recognise the necessity for a definite wear limit on a gauge. In many cases there is no periodic checking, in others the checking is entirely haphazard and confined to some of the more important gauges only. This state of affairs often results in the limits to which the articles are produced in the shop varying from those which are called for on the drawing.

The question of wear on a gauge is an interesting subject and cannot be neglected, since every type of gauge is affected.

Take the case of a hole to be a bearing for a shaft. Assume that the widest limit which can be allowed on the hole for its proper functioning alone can be denoted by the distance between the two lines A and B shown in the accompanying illustration. The hole will be gauged by a "go" and "not go" plug gauge, and the manufacturer of the plug gauge must have a tolerance just in the same

way as the manufacturer of the component, only it is advisable that the tolerance for the gauge-maker shall not be more than 10 per cent. of the tolerance in the component. This tolerance is denoted by small cross-hatched sections close to the lines A and B, that near the line A denoting the tolerance of the "go" end and that near line B the tolerance of the "not go" end. It will be seen that we have subtracted from our limit these two tolerances, and therefore the manufacturing limit has become smaller. We cannot allow these tolerances to fall outside the lines A and B, otherwise the hole may be produced outside the maximum limits for proper functioning and the part will therefore be scrapped.

Now it is obvious that the larger the tolerance which can be allowed for the manufacture of the hole the more cheaply can the hole be produced, and if we make our gauge as we have shown already, we know the "go" end of the gauge will wear, and immediately it does so its size will fall outside the line A and the gauge will be scrapped.

A gauge must have a certain length of life; it is not commercial to buy a gauge and scrap it immediately it has been installed in the factory; so in order to allow for the wear on the "go" end we must make the "go" gauge of such a size as is shown by the dotted section E. When the gauge is new the tolerance in the shop will be EB, and as the gauge wears it will get larger and larger until the full tolerance is available, after which the gauge should be scrapped.

If the largest tolerance that is possible for correct functioning has been fixed in the first place, we must reduce that tolerance by, first of all, the manufacturing limit in the gauge, and, secondly, its wear limit, in order to obtain the manufacturing tolerance left for the shop. If, however, a tolerance of a certain amount has been fixed upon, and this has been increased to a large extent by the wear on the gauge and the parts still function properly when assembled, it will be clear that our tolerance has not been correctly fixed at the outset and our parts have not been produced at the best commercial value when the gauges were new.

The wear limit will depend on the frequency of inspection of the gauges and also on whether the gauges are of a nature to allow for this wear to be compensated—that is, whether they are adjustable or whether they are solid.

It will be clear that an adjustable gauge can be readjusted at far less cost than a new solid gauge can be supplied, and therefore the adjustable system of gauging enables the manufacturing tolerance to be as large as possible, since its manufacturing tolerance and wear tolerance are an absolute minimum, whereas in the solid gauge the wear tolerance has to be balanced up with the cost of the gauge for replacement.

The adjustable gauge, however, must be of such a design that it is easily possible to obtain a setting of extreme accuracy; that once the setting is obtained it is immovable by use or misuse; and that the gauge is tamper-proof and cannot be permanently deformed by dropping on the floor. It was to overcome these disadvantages in adjustable gauges that the special types of gauges illustrated in the paper were designed. The method of obtaining the final adjustment in them is unique, insomuch that it is secured by the compression of a hardened steel ball between the anvil and the

adjusting screw; an accuracy of setting of 0.00011in. is easily obtained, while the act of compressing the steel ball makes backlash in the mechanism an impossibility.

It is no exaggeration to say that even to-day in the automobile industry the problem of the commercial inspection of parts is in its infancy.

The gauging of splined shafts on which gears slide is haphazard and yields no useful result. The splined ring which goes on the shaft and the splined plug which goes in the hole may tell us that the parts will assemble. The quality of their assemblage is an unknown factor. No tolerance is placed on the spacing of the splines, so that it is impossible to tell how many of the splines will carry their proportion of the torsional load. Very few splined shafts are ground in the splines after hardening, and they are therefore subject to distortions from that treatment. No British standard of spline shafts or gauging spline shafts exists—this in the year 1922.

There still appears to be a widespread idea that tool-makers can make gauges and even jigs to what they blithely call "dead-size dimensions." It is obvious that no such thing as a dead-size dimension can exist, and that a gauge and a jig must have tolerances which bear a close relation to the component which they are either to gauge or produce. Those who claim to make gauges and jigs to dead-size dimensions are usually so poorly equipped with instruments of measurement that they cannot detect the error, or the instruments are so easily influenced by the personal element of the user that they do not detect the error, and, as usual, because this error is not visible, it is assumed to be non-existent.

Firms send jigs out to be manufactured to prints with dimensions on them surrounded by stars, and a note in a corner of the blueprint that the dimensions so marked must be adhered to absolutely. A definite limit is asked for, but the chief draughtsman states that no limit can be allowed. In other words, the firm that require the jigs do not know what they want and yet expect another firm to produce it. The conscientious inspector of the firm who attempt to make the jigs, who is equipped with all the modern up-to-date appliances of measurement, cannot get to know the customer's requirements, cannot find what the jig is for, and yet is expected to pass or reject it either as correct or incorrect. Many hours are spent in obtaining centre distances for reaming holes in a jig to the finest limits possible. It is afterwards discovered that these holes have perhaps $\frac{1}{64}$ in. clearance over the part which has to fit into them; thus a considerable waste of time and money is involved. A good rule for ordinary work is to allow in the jig one-third of the tolerance on the component. In some cases this is not possible where the tolerance on the component is very fine.

The inspection of gears is another feature which requires complete reorganisation. Years ago it may have been necessary, due to the crude methods of gear production, to know that one gear would roll freely on another, but such a test is not stringent enough for modern gearing. It is no test whatever of the ability of the gears to give uniform angular movement on which silence and wear depend. The spur gear testing fixtures at present used give a result which may be a conglomeration of all the errors that exist, those such as eccentricity, irregular spacing and bad tooth form being amongst the most important. It is practically impossible to sort out which particular

element is at fault. Accuracy of tooth form itself is useless unless the tooth is in the right position.

It is interesting to notice what takes place in a gear box of a car with a gear of 30 teeth running at 1,800 revs. per minute with a spacing error of 0.002in. from one tooth to the next due to distortion in hardening or similar causes. The gear makes 30 revs. per second. There are 30 teeth on the gear, and therefore 900 teeth per second come into contact. Suppose the oncoming tooth to be 0.002in. nearer its neighbour than it should be. This tooth will take up the full torsional load almost immediately on coming into engagement. The actual distance of movement, for the sake of argument, we will suppose to be 1-500th part of the circular pitch. The mating tooth will be accelerated 0.002in. in 1-450,000th part of a second, which is equal to 75ft. per second per second—nearly two and a half times the acceleration due to gravity.

At one end of the system we have the flywheel, big ends and crankshaft revolving, at the other end the propeller shaft, axle shafts and road wheels, both systems of large rotational inertia augmented, if the acceleration is a minus one, by the driving force on the pistons. The force required to give an acceleration as high as this will cause the gear teeth to bend, and the blow of their coming into contact will set up the ordinary gear noises.

It is the writer's opinion that if two gears could be produced with a negligible error in spacing and concentricity, properly mounted, their action would be soundless; but means must be developed for accurately checking the errors of a gear separately as well as collectively, as no improvement can be made in an article until means are at hand for accurately measuring its errors.

It will be seen that a gear with errors such as those stated might roll quite satisfactorily on any testing fixture, and that its objectionable qualities would become apparent only at high speed and when heavily loaded.

The section of the paper on inspection relating to the gauging of screw threads helps to a very great extent to clear up this misunderstood subject. Ideas of thread gauging have been built up from the conceptions of plain gauging to which we have become accustomed in the last few years. Different kinds of fits have been specified for shaft and hole work, and before actual limit gauges were in use the skilled man often determined his class of fit by the "shake" of the standard plug gauge in the hole. This system has resulted in a custom which it is no exaggeration to say exists in every works or factory in the world: that is the judging of the quality of a screw by its "shake" either in a tapped hole or in a ring gauge. It has not been realised that the requirements for gauging screws and for gauging plain shafts and holes are entirely different. The screw is used in order to withstand an axial load or pull, and its quality can be determined only by its ability to withstand such a load. The only places where a screw can take axial load are on the flanks, and therefore the quality of the threads of a screw will be determined, first, by the area of its flank contact, and, secondly, by a measurement of what is known as its simple effective diameter—that is, the effective diameter as obtained on a measuring machine with needles—and is really a measure of the amount of metal which has to be sheared before the threads give out.

It will be obvious that a screw which is tight in a gauge or tapped hole may have no flank contact whatever, but if it has, this flank contact may be at either end of the screw due to pitch error—a few threads only of the length of engagement will be bearing the load; whereas a screw which has good flank contact all the way down may be slightly below size on all its diameters and shake, but is far superior to the one with no shake from a quality point of view.

If it were a practice to pin articles together whereby the pin was forced into the hole, the pin's ability to withstand load or pull would depend upon its type of fit in the hole, and our system of gauging would closely resemble that of a force or drive fit for a shaft and hole, but the threads on a screw are there solely to withstand this axial load, and we know that, provided the size of the bolt shank and length of engagement have been proportioned correctly, its ability to withstand load will be, as before mentioned, a measurement of its simple effective diameter.

In gauging a screw, therefore, there is needed, first of all, a gauge which tests all its elements collectively to show that nothing is too large—this gives interchangeability; and, secondly, it is necessary to have a measurement of the simple effective diameter of the screw—that is, the effective diameter over one thread; this gives the limiting amount of metal which can be removed from the flank of the thread either by thinning or by a complete reduction in size of the screw, and so puts a definite tolerance on the quality or mechanical strength; this is done in the Wickman adjustable thread snap gauge supplied by Messrs. Alfred Herbert, Ltd. The front anvils are made of full form type and test the length of engagement of the screw. They are set to nominal size by means of a master plug screw gauge, and any screw passing through cannot be too large on any of its elements. The second or "not go" effective diameter anvils consist of one thread at the top and two at the bottom, which are cleared on the root and the crest and touch the flank of the thread around the effective diameter only. If these are set below nominal by a certain limit, any screw which is too small on effective diameter will pass through and be rejected.

If the screw has a pitch error over the length gauged, its effective diameter over the length of engagement—that is, its compound effective diameter—will have increased by approximately twice its pitch error, and therefore, for the screw to pass through, its simple effective diameter—that is, the effective diameter of one thread—will have to be reduced either by thinning the thread or by completely decreasing the diameter of the screw on its elements by the same amount, namely, twice the pitch error.

If, however, this reduction in simple effective diameter, necessary for the screw to go through the "go" anvils, is not larger than the tolerance placed between the "go" and "not go" anvils of the thread snap gauge, the screw will not go through the "not go" anvils, and therefore the pitch error in the length of engagement is not in excess of that allowable for the particular quality of screw. If, however, the pitch error is so large that the compensation of effective diameter required to go through the "go" anvils is larger than the difference between the "go" and "not go" anvils, the screw will pass the "not go" anvils before it passes the "go" anvils.

This system has lately been developed for the testing of taps, thereby providing a commercial method of producing a tapped hole

within predetermined limits of accuracy; the two combined form an ideal system for the production of interchangeable threaded work of any given quality. Recommendations of tolerances for four different grades of screws will shortly be published, together with commercial limits for taps to produce holes of corresponding accuracy.

Here is another difference between the gauging of screws and plain shafts and holes. In shaft and hole work it is usual to specify that the hole shall be a standard and that the allowance between the shaft and the hole, in order to give proper functioning, shall be made on the shaft itself. These allowances vary according to the different types of running fit required.

In screwed work there is only one allowance—the allowance between the largest screw and smallest hole in order to avoid interference. No such thing as either a standard hole or a standard screw exists, since it is of no advantage to make the hole any more accurate than the screw, as the load borne by the threads of the screw is borne by the threads in the hole, and the weaker of the two will always go. It may be argued that in cases of studs which have to be removed occasionally it is an advantage to make the hole better than the screw, as it is easier to replace the stud than to replace the component, but a moment's consideration will show us that, however accurately the hole is made, if a bad screw is put in and spannered up, the threads of the hole are displaced—that is, partially sheared—in order to mate up with the inaccurate threads of the screw, and all the accuracy put into that hole is wasted. For a case of this sort a higher quality should be specified in the hole and on the screw. The ring gauge cannot in itself give any idea of quality in the threaded work that it checks.

It has been stated that the pitch error in a screw will increase its compound effective diameter—that is, its effective diameter over a certain length of engagement—by approximately twice its own amount. This tends to wear ring gauges on the effective diameter only and produce screws which are very much over size when tested over their length of engagement, but which, when tested by means of needles, appear to be below standard size. This wear on the ring gauge is not easily apparent by any checks which are usually employed. A ring gauge is retained in use because it still passes its "go" and "not go" checks when its compound effective diameter is very much above standard. The screws passed by the ring gauge are also very much above standard, and it is necessary to employ taps which will cut a thin thread—that is, a thread of large effective diameter in the hole in order to let the screw in. Very often a good tap is condemned as cutting too small because a screw which passes this oversize ring gauge will not enter.

Another point of importance is the tremendous difference between the equipment of the machine operator as regards measuring appliances compared with that of the inspector. The most important part is that scrap should not be made and the machine operator should be equipped with means for setting up his tools identical with those in the hands of the inspection department. It was for this reason that the adjustable thread snap gauges and plain gauges designed by the writer have been made exceptionally strong and heavy, so that they can be placed in the most unskilled hands without fear of damage. Their adjustment also enables them to be set

to slightly finer limits than those used in the inspection department, so that any article which passes the setter-up must pass the inspector also. With a system of this kind the mysterious hang-ups and stoppages of production which occur at most uncanny and irregular intervals in practically every works that produces screws can be entirely eliminated. The tap gauges prevent any tap outside the maximum limits available being employed in the shop. The thread snap gauge in the same way checks the production of the screws.

Another misconception that has to be fought against, and which has also been handed on from the practice familiar in gauging plain shafts and holes, is in connection with the tolerances necessary for commercial screwed work. Ninety per cent. of the shop people, when shown the B.E.S.A. tolerances, immediately shy at their apparently large figure, because they are still used to plain shaft and hole work and measure screws on the outside diameter.

Taking a 10 per inch screw made to B.E.S.A. tolerance, the amount of metal removed from the effective radius of the thread is not more than 0.0032in. or 0.0016in. from each flank, so that the worst screw and nut within these tolerances have a mechanical strength of not less than 93.6 per cent. of what they would have if the screws were absolutely perfect; and such a screw, in spite of the fact that it fits loosely and with a considerable amount of shake, will, when tightened up, bear its load satisfactorily and will not easily come loose owing to vibration, which is nothing more than a highly alternating load. This does not mean that locking devices can be dispensed with entirely, as these are always necessary, but a screw which was inaccurate and tight, due to its fit on the major diameter or on two or three threads only, would constantly give under load and become loose. The nut might not actually spin off, but it would have to be repeatedly tightened in order to bear its load.

AXEL C. WICKMAN.

Messrs. Alfred Herbert, Ltd., Coventry.

In *Engineering Production* for April 20th was published a discussion on Mr. E. Fairbrother's paper on "Inspection Methods." In this discussion the President of the Institution of Production Engineers somewhat depreciates the work done by the British Engineering Standards Association in fixing screw thread tolerances. He states that "in the chart there is given a maximum clearance between nut and bolt of 12/1000ths of an inch for a ½in. bolt, and that on a bolt of ¼in. diameter with 20 threads per inch the thread was not much deeper than that, and that they could almost pull the nut off by hand." It is evident from these remarks that the President of the Institution does not understand the B.E.S.A. limits in that the tolerance on screws is based on pitch alone, and not on diameter, so that the tolerance for a 20-thread per inch screw ½in. in diameter would be smaller than that for a 12-thread per inch screw ½in. in diameter.

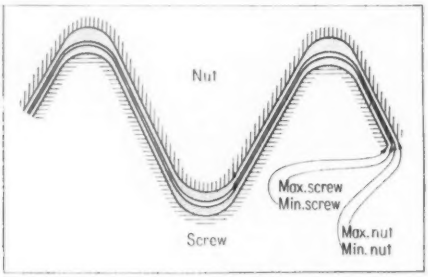
The fact that a statement of this kind should pass unchallenged among the large number of engineers present shows how little the subject of tolerances for screw threads is understood, and that the splendid work which the B.E.S.A. has done has been, to a great extent, wasted owing to want of appreciation.

The accompanying diagram shows a 10 threads per inch Whitworth

screw and nut made to B.E.S.A. tolerances. The limit on the effective diameter, viz., −0.0063in. (which some people hold to be unreasonably large), means that each thread is thin by approximately 0.0032in., or only 0.0016in. taken off each flank. It will be obvious from the drawing that such a screw has ample mechanical strength and could not very well be pulled off by hand.

Mr. A. A. Remington, in his interesting letter to *Engineering* on March 10th, 1922, says:—

"It is not generally appreciated that a nut that is a nice spanner-tight fit on a bolt does not usually or necessarily attain that condition by extreme accuracy of its various elemental dimensions, but more frequently by a combination of inaccuracies that necessitate and permit plastic flow on the thread faces to take place as the nut is screwed on. If no such action takes place the nut is, in all probability, not spanner-tight. It is, of course, important that the amount of plastic flow necessitated in order to pass the nut shall not be so great as to cause permanent damage to the threads to such a degree as to affect their strength. In hard metals, such as cast-iron and, to a less degree, aluminium, this is a most important



matter, as little plastic flow is possible, and, in consequence, very high stresses may be induced in screwing a stud and threads of a degree of inaccuracy that are quite satisfactory for steel are useless, and in extreme cases may even cause complete stripping of the thread."

It seems to us important that we should decide definitely which of two things we require in screws: whether the nuts should be spanner-tight or whether the screw shall have a definite load-bearing capacity or mechanical strength. The first is absolutely independent of the second; in fact, it can be said that a screw which is a slack fit in a threaded hole, but on which a definite limit has been placed on the simple effective diameter, will be more efficient than a screw which is simply made spanner-tight, no limit being placed on its mechanical strength or quality.

Many engineers assume that the tolerances for screw threads recommended by the B.E.S.A. are too coarse for their requirements because they look large. They are thinking of plain shafts and holes. If they were asked what means they possessed of determining the limit on the simple effective diameter of the screws which they produce, they must reply that they have no such means; therefore, their contention is based on opinion, and not on facts.

It was to provide a simple and commercial method of producing screw threads to B.E.S.A. or any other tolerances which may be suitable that the Wickman adjustable screw and tap calliper gauges were introduced. These gauges have met with a favourable reception in this and other countries, as they form a quick and simple method of controlling interchangeable threaded work to any predetermined quality or mechanical strength.

We cordially agree with the President's concluding remarks that it is highly desirable to ensure by proper inspection methods during manufacture that the work is made correctly in the first place so as to save as much as possible inspecting work after it is finished. Inspection is the keystone in the arch of production, enabling work of a definite quality to be produced at the lowest possible cost.

Coventry. J. PICKIN.

For Alfred Herbert, Ltd.

THE

INSTITUTION OF PRODUCTION ENGINEERS.

A GENERAL Meeting was held at the Institution of Mechanical Engineers, Storey's Gate, London, S.W.1, on Friday, April 21st, 1922, the President, Mr. Max R. Lawrence, being in the chair.

The minutes of the previous meeting were read and approved.

It was announced that Mr. Max R. Lawrence had been re-elected as President for the 1922-23 session, and that Messrs. W. L. Fisher, H. E. Honer, and J. D. Scaife had been elected as Vice-Presidents.

Mr. J. R. Smith then presented his paper on the subject of "Electricity in the Modern Engineering Works."

It was announced that the next meeting would be the Annual General Meeting, and that full details relating to this function would be stated later.

Votes of thanks to Mr. Smith for his paper, and to the Institution of Mechanical Engineers for the loan of the Hall, concluded the proceedings.

ELECTRICITY IN THE MODERN ENGINEERING WORKS.

By Mr. J. R. SMITH, A.M.I.E.E., Chief Electrical Engineer, Messrs. J. & E. Hall, Ltd., Dartford.

The title of this paper has been suggested by the rapid progress and development of electricity as applied to almost every process associated with the engineering industries of the present day. In addition, however, its present and future possibilities have to be realised in connection with the generation of power and light and in its application to electro-chemical and other processes.

It may be truly remarked that no other known form of energy can compare with electricity because of its many forms of application. In the past twenty years there have been many changes made from mechanical to electrical application of power, with results that could not be rivalled in any other field of engineering. Hydraulic and pneumatic transmission of power has been tried under various conditions, but without definite remunerative results.

Looking back on the earlier attempts to introduce electric power and light, and reviewing the conditions of those times, it will be realised what achievements have been attained within comparatively recent years. The author well remembers the time when electricity was looked upon as a novelty and an expensive luxury, not to be indulged in on a commercial basis.

We owe much to the early research work of men like Kapp, Siemens, Crompton, Ferranti, and others, and, of course, to Parsons and other inventors and engineers who improved the steam turbine, making possible modern developments.

If present-day conditions be examined, it will be found that electric power enters into practically every process, the execution of work being economically and reliably effected. It may be said that the twentieth century is an electrical period as the nineteenth century was a steam age.

In some respects progress in this country has been retarded in matters electrical principally because of the absence of large sources of water supply such as are common in America and on the Continent. As a result, until recently, the installation of high tension transmission power supplies was on a limited scale. This state of affairs has been greatly altered in recent times—thanks to the development of large power units operating under more economical conditions.

The transmission of electrical power, although existent for small areas at low tension in this country, could not compete with local power units until a more economical form of generation became possible. Much has been written concerning long-distance transmission and its possibilities, but with the wider knowledge now possessed its limitations are readily recognised, and, in consequence, its development in the future will take place within well-defined lines.

Schemes and proposals are now under consideration in many parts of the country relative to a more economical power supply. As these projects get under way, the necessary impetus to a trade

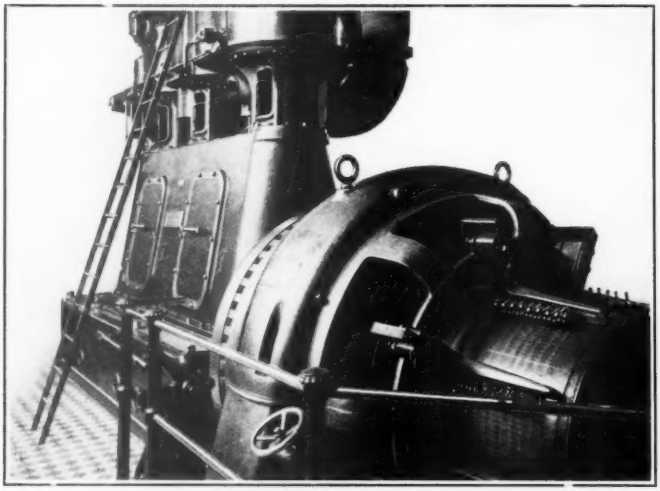


Fig. 1.—A 400 k.w. compound-wound generator and single expansion surface-condensing engine.

revival should be forthcoming, and our industries will certainly be placed on a better competitive basis in the international market. Such must, however, be regarded as periods of development limited in the main by the capital expenditure involved, and will, therefore, advance in accordance with the facilities afforded.

Referring to the conditions now obtaining, we find that engineering works may be classified under three groups: first, small works which derive their power from small prime movers situated in or near their sphere of operation, external power from other sources not being available or proving too costly. For such works the internal combustion engine usually gives economical results, and

being simple in construction and operation can be tended by semi-skilled labour.

In the case of larger concerns, however, one usually finds that steam can show good results and is more reliable in operation. Very low working costs may be taken as the rule with the modern high-speed surface condensing units, making it extremely difficult to justify recourse to external supplies, especially if the plant under consideration can show a good load factor.

Secondly, there are larger works running under similar conditions which are able to operate more economically because of the higher efficiency of their prime movers. Then there are works so situated that they can obtain an external source of power at a lower cost than can be generated locally. In each instance the existing conditions will naturally govern the choice of unit for power production, usually based upon the cost of fuel or other controlling factors.

In the third case, there are works—some large, some small—obtaining an external supply of power which is quite justifiable provided that it can be definitely shown that certain beneficial features exist, such as lower costs and economy of space. In such cases, the external sources of power can compare favourably, particularly if future extensions are contemplated.

It is of the greatest importance that all the factors in the case be considered when selecting a power supply, as, although figures can be advanced in favour of external power, yet it may be possible to show better results with local units under certain conditions.

Dealing now with the important subject of power supplies for workshops, the usual method of obtaining power is by means of direct current generators running in conjunction with a suitably arranged switchboard distribution, and, provided that the power house is in a fairly central position, economical working can be maintained.

The choice of voltage is an important factor and one in which much saving in first costs may result. During the last fifteen years the electrification of works has passed through various stages. In the earlier schemes 100 to 120 volts was usually adopted as a working pressure, possibly due to the fact that higher voltage motors were not then sufficiently perfected. Although the 110-volt motor has given good and reliable service, yet the cost of its large copper cables due to the high amperage makes its first cost considerably higher than for systems of higher pressures. Although this disadvantage is obvious, yet it must be remembered that the low-voltage machine usually gives less trouble than the high-pressure machine.

For modern practice, however, it is realised that pressures of 230 and 460 are now quite suitable and conform with the general conditions of internal or external sources of supply. The shunt or compound-wound machine at, say, 460 volts is quite reliable and

efficient, standing up to its work and being equal to the 110-volt motor in its performance. The question of cable insulation for the higher pressure and the requisite precaution for safe working, of course, become of greater importance, and the maintenance charges are rather higher.

It is an extraordinary fact that one may visit some of the largest works in the country and find 110-volt systems in operation, no doubt owing to gradual developments having been made at this pressure until in the end it has become inexpedient to make a change to a higher voltage.

For works power, shunt, compound, and series wound machines are suitable for all ordinary purposes. For line shafting the shunt-wound motor will usually meet all requirements, since it has a comparatively uniform speed for all loads, is of simple construction, and easy to start. Possessing a good torque, it is employed almost universally for this class of work. There are, however, other considerations to be taken into account in connection with shafting drives. One usually finds a large motor driving long lines of shafting that operate a considerable number of machines through belting. Although this is a convenient method, yet the question of ultimate costs should not be overlooked, and consideration should be given to the power required to drive the shafting and belts light, relative to the useful work performed. A large amount of power may easily be consumed in lost motion. These factors are of importance. When power requirements for shops are put forward, the grouping of machine tools is the first consideration, and, by judicious arrangements, much lost power can be avoided. Large machines that deal with work requiring time for setting up, and absorb, say, 10 h.p., should be provided with individual motors in preference to being driven from line shafting. It is seldom advisable to group shafting to take power above 20 h.p., owing to losses in belt transmission, etc.

Another point deserving of more attention is the position of motors. It appears to be thought in some quarters that once a motor is installed and running it is there for ever and will not require further attention, and, in consequence, can be placed in any inaccessible place.

To maintain an efficient service, motors should be placed in such a position that they may readily be inspected from the ground. They should also be within easy reach of the crane that serves the section they drive. As to power transmitted through belts, much may be said on this important point. Sufficient attention is seldom paid to this kind of power transmission, with the result that the upkeep of machinery is increased.

Although well-defined data are available relative to efficient means of belt transmission, this, in many cases, does not enter into the calculation of the official responsible for the layout of the shop. It will usually be found that the widths of pulleys and

belts are too small for the load to be transmitted, resulting in great strain and loss of power. The ratios for driver and driven pulleys should also enter into these calculations. It is bad practice to give a greater ratio than 5 to 1 or *vice versa*. It is also inadvisable to raise the belt speed beyond 4,500ft. per minute.

The author has in mind a case where a motor driving high-speed grinding machines running light develops 9 h.p. When the load is applied a further 2½ h.p. is recorded; thus the efficiency of such a drive is extremely small, and it is obvious that the more efficient way would be to drive these high-speed grinders by means of individual high-speed motors.

A further instance of a similar kind was recently brought before the notice of the author. An exhaust fan utilised for removing sawdust and shavings from carpenters' and pattern-makers' shops was driven through a countershaft from line shafting. It was found, however, that the amount of power required from the shafting motor was out of proportion to the fan duty. In addition, this drive gave considerable trouble due to small pieces of wood passing through the fan blades, and the belts could not be kept sufficiently tight. This fan was eventually coupled directly to a motor and current readings taken. It was found that the power absorbed by direct drive was one-third of that taken when the fan was driven from a countershaft. Moreover, since the conversion, this fan has not given trouble of any kind.

Referring to motors for independent machine power, care must be taken in the selection of such machines. The manufacturers of machine tools usually give the maximum power required to drive their particular machine tool, but it is also advisable to consider the nature of the work upon which the machine will be engaged. For instance, in one case the machine may be required for heavy duty, such as roughing out or similar work which will absorb a large amount of power in consequence; but, on the other hand, a machine of this type may be engaged upon a considerable proportion of light work with only an occasional heavy duty job. It will thus be seen that, although in some cases it is advisable to install a motor of the maximum horse-power, yet since the difference between intermittent heavy duty and much lighter work is proportionately large, it might be advisable to use a smaller motor with, say, a half-hour rating for peak load conditions. It is seldom found that the maximum horse-power as given by the manufacturers can be maintained continuously. As a case in point, a certain high-speed lathe came under the notice of the author. The makers stated that this machine required a 10 h.p. motor to give full duty. Such a machine was provided, and careful readings were taken on heavy work with the maximum speed and feed recommended. It was found, however, that to develop 10 h.p. the belting would not stand up to the work, and the cut proved far too heavy for the machine. Several lathes of

similar pattern were eventually installed and driven by motors of 7 h.p.

Another type of motor is often used in connection with machine tools, and is one that can be recommended with confidence. Reference is made to the variable speed shunt machine. With this class of motor, gearing and cone belt drives may be reduced to a minimum and higher efficiency obtained, and often more accurate work is produced. By the judicious selection of these motors it is possible to increase output by 30 per cent., due principally to the flexibility of control.

The application of individual motors to machine tools has played no small part in the rapid development of certain classes, chiefly planing machines, milling machines, high-speed drills, high-speed grinders, etc., but in the view of the author the most modern application is that of the planing machine. By means of variable speed motors it has been possible to increase the number of operations which can be undertaken at one setting, thus effecting a saving in time and power and gaining the advantage of the greater precision which attaches to the machining of work at one setting.

For example, there is a machine of the planer type electrically driven and controlled which planes longitudinally and transversely and slots at one setting. The motors in this instance automatically operate as power or self-act according to the functions to be performed. The operation is under perfect control from the machine attendant's position, long or short strokes being adjusted without stopping the machine. In addition, the speed can be varied on the cut, on the return, or between given points. Thus it will be evident that such a machine is far superior to the ordinary belt or motor-driven planing machine. In this connection, it may be stated that in an engineering works in the North of England one planing machine of this type displaced seven ordinary machines and turned out more work in a given time.

A new type of motor has recently been developed for industrial purposes, and it possesses characteristics not found in the shunt-wound motor, namely, constant torque for variable speed. It is a three-phase machine arranged with a variable number of poles, the combination or grouping giving certain fixed speeds, such as 375, 500, 750, 1,000, and 1,500 for fifty cycles. This machine is of the slip-ring induction type, and is controlled by means of a tramway type drum. Without resistance of any kind, the machine conforms to requirements for machine tool driving, and, as it possesses slip rings only (that is, no commutator), it should find a place in modern engineering shops.

As polyphase supply in the future will be the chief medium employed for lowering the cost of power, it is obvious that where alternating current motors can be applied under such conditions they should surpass the direct current unit, provided that a reasonable power factor can be maintained. In the opinion of the author

we are on the eve of further development in this direction. Reference is made to the synchronous induction motor operating at unity power factor. Although this type of machine has only recently been placed on the market, it is possible that there will be vast improvements effected in this class of motor.

Other applications, such as electrical heating, printing, welding,

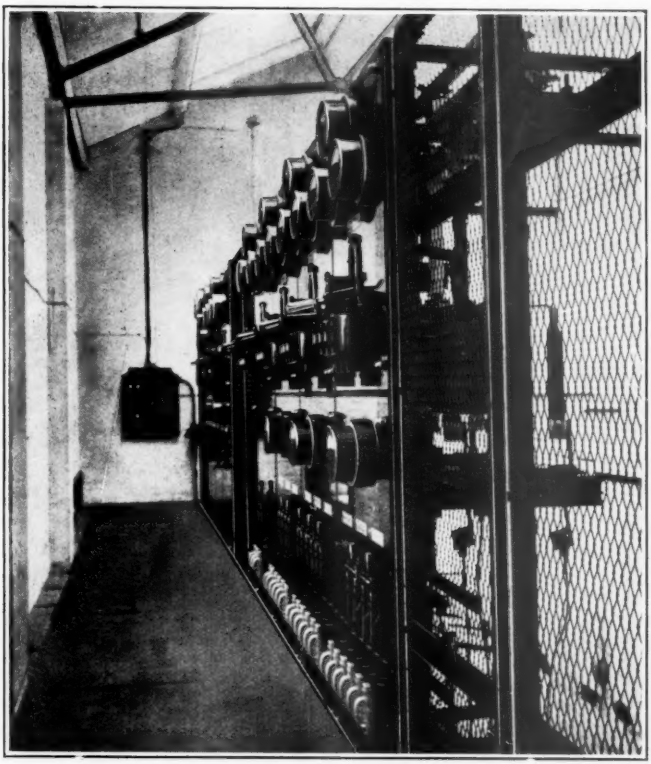


Fig. 2.—A high and low tension control switchboard in substation.

etc., will now be considered. Electrical heating is naturally regarded with suspicion, due to the high cost and relative small heat values. We have not yet been educated in the appreciation of the possibilities of electrical heating. One is apt to regard it in a similar manner to other forms of heat, such as gas, oil, or coal fuels requiring an escape for the spent gases.

In the application of electrical heating, one must treat the problem from a scientific point of view having regard to the fact that as no air is required for combustion, no duct or chimney is necessary for the waste products. In consequence, electrical heating units may be housed in an air-tight chamber, the outer casting being heavily insulated to prevent losses due to radiation.

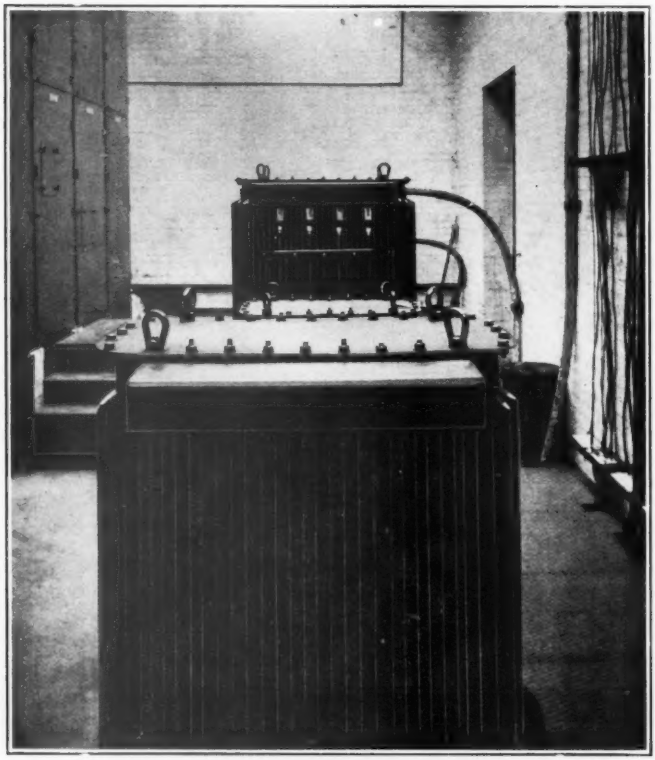


Fig. 3.—A high tension transformer and switch cubicles.

If due regard be paid to these points, it will be found that very economical results at reasonable cost are possible. Coal, oil, and gas have extremely low heat efficiencies due to the amount lost in flues and air inlets, whereas electrical heating under conditions similar to those described can show very high efficiencies, especially in the case of entirely enclosed chambers. We all know

that the so-called hay-box cooker is efficient, due to similar conditions, therefore with electrical heating one can realise that much stronger claims can be put forward on the ground of greater efficiency than is possible with coal, gas, or oil.

As an example, some fifteen years ago the author introduced an electrical glue-pot, having a water capacity of two gallons. This consisted of a copper tank about twelve inches square and some eight inches deep. Near the bottom were placed two butt-ended tubes, and, immersed in the water, inside these tubes two electrical heaters were placed and sealed. The outside of the tank was insulated with slag wool, the whole being placed in a sheet-iron case, the glue-pots being inserted from the top in the usual way. It was found that once the water had been brought to a temperature of 212° F. the current could be cut off for two or three hours, according to the demand for glue. Several electrical glue-pots were eventually installed under similar conditions, and were found to be in every way satisfactory. The charges for upkeep were practically negligible, and on the ground of cost of heating they compared favourably with gas. Moreover, the risk of fire was reduced to a minimum, an important consideration in the case of a carpenter's or pattern-maker's shop. This is given as a simple illustration of the possibilities in electrical heating as applied to enclosed systems.

Another application is that employed for drying blue prints, etc. With the automatic photo-printing machine, operating in conjunction with automatic washing apparatus and electrical drying by means of heated screens or mats, it is possible to turn out prints at a speed quite impracticable if resort be had to ordinary heating methods. The author recently timed a full-size print from its insertion to delivery, and the printing, washing, and drying occupied less than five minutes.

Again, when accurate measurements of heat, such as heating water in jackets or transfer of heat, are necessary, no other form of application can compare with electrical heating, provided that the proper precautions for radiation losses be taken, the input of electrical energy being almost proportional to the heat units given off.

Mention has been made of photo printing, and in connection with this, to set out some items of interest may not be out of place.

It is well known that the most successful method of obtaining duplicates from tracings, etc., is by means of arc lamps, with suitable arrangements for passing the tracing and sensitised paper before the light. In the early days the usual equipment consisted of a vertical glass cylinder around which were strapped the paper and tracing, the arc lamp being lowered slowly into the cylinder and again raised, the duration of exposure being largely left to the judgment of the operator. This method was not very

successful for several reasons, such as the speed of travel being irregular, some parts being over- or under-exposed, varying candle power of lamp due to swing, etc.

Later there was introduced the horizontal automatic machine, which was furnished with a number of arc lamps. Prints could be obtained in a much shorter time, and, provided that the time exposure (in this case proportionally to speed of the paper) was correct, very good results could be obtained. The only drawback

Fig. 4.—A 7 h.p. enclosed motor driving lathe through silent chain.

was that when old and new tracings were passing through at the same speed the dirty tracing necessarily resulted in a print under-exposed. This automatic machine was eventually improved, and with two sets of prints the light can be varied as desired.

The latest type of photo-printing machine again reverted to the moving arc, but, in conjunction with moving prints, the candle power and voltage of the arc were greatly increased, also the speed of prin . This development has been carried so far that it is now possible to pass the prints through the machine in one

minute and obtain excellent results, the automatic washing machine performing its function in two minutes—electrical drying in two minutes—the prints coming out flat and free from creases or blurs.

Dealing now with electrical welding, we enter on a branch of modern electrical science, and one in which much remains to be discovered.

The two systems that are best known are arc and resistance welding. As engineering appliances, they date back some twenty years.

Arc welding may again be divided into three classes: (1) long

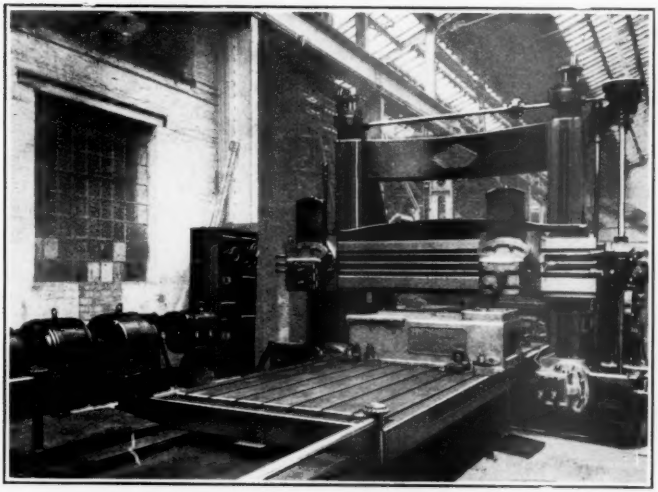


Fig. 5.—An example of an electrically driven and controlled planing machine.

arc and short arc welding with metallic electrodes; (2) carbon arc, with metal feeding (these being used with direct current only); and (3) short arc, single-phase welding with metallic electrodes through the agency of reactive transformers.

The arc welding systems usually found in modern workshops comprise the "Quasi" system, in which flux-coated electrodes are used, the object of this flux being to prevent oxidation of the metal deposited by the arc. In practice it is found, however, that this flux is not beneficial on certain kinds of work, and therefore a bare metal electrode is used.

The usual procedure is to make the work to be welded negative

and the electrode positive. Recent experiments, however, have proved that it is sometimes better to make the work positive, as a larger amount of heat resides in the positive pole, and in consequence the penetration is deeper. If this be done, greater care must be taken with the amount of current used, or a granular arc will result.

The usual voltage of the " Quasi " arc is 45 to 55, current being regulated by means of a graduated line resistance. It is of importance that the amount of current is proportional to the dia-

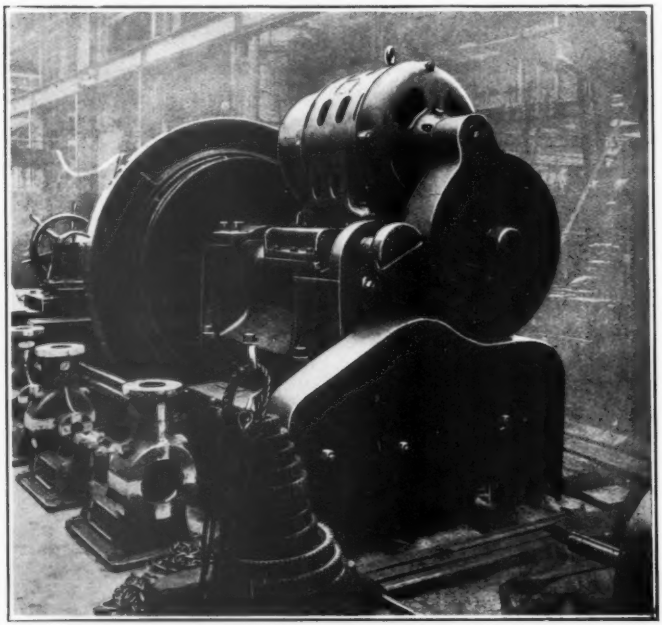


Fig. 6.—A three-phase motor driving lathe through helical gears.

meter of the electrode. The section of the electrode should be proportional to the nature of the work.

With wrought iron or steel, excellent work may be done, and much material can be made good which would otherwise be scrapped. No difficulty is experienced in machining wrought welds, as a soft junction results between the deposited metal and the wrought material.

The short arc is a modern development, and has a future especi-

ally for certain kinds of work, such as the welding of sheet metal, usually too thin for the long arc; although its best sphere of operation is that known as automatic welding. A well-known British firm has recently developed the automatic arc welder in connection with the reinforcing of large turbine shafts, and the results obtained are such that detection is hardly possible after the shafts have been machined. The lowest voltages for the short arc being 19 to 25, it is usual to make the work positive for reasons already stated.

The carbon arc fulfils certain conditions not possible with the metallic. When used in conjunction with a metal-feeding strip, complete welds occur even on plates up to 1in. thick. In this instance it is unnecessary to prepare the work by "veeing" out the metal, as is usually required for metal arcs, the penetration being deep, the weld sound, and capable of sustaining strains equal to solid metal.

This system has been developed as an automatic operation by a firm in America. They claim to be able to weld up thick steel plates, and to retain the strength of riveted work. Their first automatic machine may be seen in the North of England under demonstration conditions.

There is one material that does not always give successful results, namely, malleable iron, for, although a weld may be made, yet the strength is such that no dependence may be placed on it.

With regard to cast-iron, this, under certain conditions, yields to treatment, and, provided that care is taken to avoid strain due to expansion and contraction, many castings may be repaired. It is, however, absolutely essential that the work should be clean and free from sand or slag. Pressure-tight casing may be welded but reliance cannot be placed on this class of work.

Single-phase arc welding is a similar process to the direct current, but it possesses certain features not found in direct current welding, viz., the arc, having no polarity, limits equal heat for electrode and work. It also requires more current per sectional diameter of electrode, and has a greater penetration in consequence. It needs a short arc for successful application. Until recent improvements were made in connection with the reactive transformer, it was regarded as dangerous in operation.

The arc may be used for welding or cutting, and also for removing surplus metal. This system requires no line resistance and is self-regulating, the arc having what is known as a constant heat value, due to the automatic regulation of the reactive transformer. For welding in wrought or cast metal it is superior to the direct current arc, but it may not be used for thin sheet metal or very light work. The power required is directly proportional to the work, no current being wasted in resistances.

The above outlines the various systems of arc welding, but as

time will not permit of enlarging on the subject as a whole in these notes, only the resistance system will be discussed.

Unlike arc welding, the resistance system consists in raising metals to the welding temperatures by means of the passage of large currents. The application of this principle in welding dates back some twenty-five years. The first known machine was patented by Professor Thompson, and consisted of a single phase step-down transformer, the primary circuit being high voltage and consisting of a number of turns suitable for the voltage and frequency of the supply; the secondary circuit being one heavy water-cooled turn was not complete until the work to be welded completed the circuit. Thus the ratio of the windings produced extremely heavy current at very low pressure, the result being that metals of large section could be brought to welding heat. The development of Professor Thompson's machine took practical form for welding railway metals, heavy bars, and similar work, and was later known as the Thompson Welding Co.'s patent.

The early application in England took the form of a machine for welding the rims of hansom cab tyres, that is, the steel ring that accommodated the rubber tyre. Since that date this class of welding has made rapid progress, greatly improved transformers, better cooling facilities and control giving a service that was not considered possible when the idea was first conceived.

The modern resistance welding machine may be divided into two kinds, flash welding and butt welding. Flash welding consists of placing the two portions to be welded in the machine, the portions being pressed together and the current switched on to heat the metal to red heat. The portions are then separated, full current applied, and the ends suddenly pressed home. The result is a flash, the metal fusing instantly, the pressure being maintained, the current cut off, and the weld completed. This system is very suitable for dissimilar metals having different melting points—for instance, copper and cast steel. Gunmetal and iron plate may be welded. "Stellite" to mild steel also forms a sound junction. The objection to this method is its sudden abnormal demand for power, causing heavy peak loads, and being single-phase it upsets the balance if power be taken from a three-phase supply.

The butt welder is operated in a similar manner to the flash, but the material is butted and current maintained until welding takes place. The work is always under perfect control, and excellent results are secured. It is possible to obtain one weld on 2in. diameter pipe in one minute. One machine has been able to make 173 welds in 8½ hours. The applications are various, and almost any class of work capable of being held in the machine can be welded.

The various applications of electrical power, as briefly described in connection with engineering works, are, of course, those found

under ordinary conditions, and do not in any way presume to exhaust this side of the question.

Each works will be found to possess its own characteristics, and, therefore, no rigid law can be laid down.

Very much may be saved in first cost and economy of operation if the problem be studied in detail and all reasonable possibilities taken into consideration.

In flexibility of operation and accuracy of power measurement for costing purposes, electrical power gives results not possible with any other form of energy.

At the present time this country is undergoing a process of reconstruction, and in this period it is hoped that some attempt at effecting a reasonable form of standardisation relative to electrical power will be made. It is regrettable that so great a diversity exists with regard to voltage and periodicity of supply. One finds all sorts of pressures, especially on the direct-current systems, and some absurd periodicities on alternating-current systems. If we are to develop along sound lines, this chaotic state of affairs must be abolished and voltages standardised.

As an example: Dover is arranged for several pressures, and 100 cycles; Highgate, 74 cycles; part of the South Metropolitan supply, 25 and 50 cycles; one of the largest power stations in London $33\frac{1}{3}$ cycles; and so forth. The American continent and also many European countries have standardised their pressures and frequencies, and there will be general agreement that no useful purpose can be served in maintaining such a varied supply as is now the case in this country.

In conclusion, the author would like to state that from what he can see of the future it appears that this country is alive to its possibilities, and, provided that all put their shoulders to the wheel, we, as a nation, shall maintain our premier position.

THE DISCUSSION.

MR. WARING-BROWN (Member of Council), in opening the discussion, congratulated the author on having presented a paper so totally different from any that had been read during the session. He had not any real criticism of the paper to offer, but one or two points had come out rather clearly, especially in regard to the driving of machines where there was a number of belts. It was astonishing what a large amount of power—and consequently money—was lost due to belts which were badly fitted. It was true that in a large works they had the production engineer responsible for the production of parts on a quantity basis, but unless he had co-ordinated the electrician's department with his own, there was no real method of ascertaining what were the actual costs. That was a point which was worthy of attention on the part of production engineers in allocating the costs of production to any item. That official must know whether his machines were running economically, because, as the author had shown, although a machine might produce an article much more expeditiously, the cost of running the machine might be quite disproportionate to the bigger output.

Among the other matters touched upon in the paper was the question of directly driving machines by electric motors. Many of those present were concerned with the manufacture of small parts on mass production lines, and it would be interesting to know where to draw the line in installing separate motors for individual machines. If they had one motor driving a group of tools and it broke down, all the machines were out of operation for a certain time, whereas it might happen that to have individual motors for each machine would make very little difference to the initial cost, and would prove a saving in case of breakdowns or where intermittent service was the rule.

MR. HARDING said he was afraid that he was rather a stranger amongst production engineers, being a maintenance man. It had always been his experience that the managements of factories were directly opposed to high maintenance costs. That could be well understood, and it was absolutely necessary to have only the best motors and the best possible maintenance, for the reason that if a large number of very small machines was installed in a factory a large amount of money could be lost by poor winding and poor attention to the motors. As the previous speaker had said, it was useful to know where to draw the line. Personally, he was of the opinion that it was preferable to group a number of machines and drive them by one motor, under certain conditions—that is, provided the voltage was right and the maintenance was good. As to welding, he would like to have heard more about spot welding. He believed that was known as contact welding, and was one means for increasing output, to a great extent, in cheap metal work.

COL. HUTCHINSON said that he also was a stranger amongst production engineers, having been concerned more with repair work. He had had, however, a great deal of experience during the late war with mobile workshops and base workshops. The fundamental difficulty then was the question of the transmission of power to the machines and the absence of foundations. They were led, in the first instance, to adopt electric power because it enabled them to provide their own generating plants and to provide self-contained electrical machines which could be rapidly installed without foundations, or with very inadequate foundations, and they could be very quickly got to work. If they had had to erect line shafting it would have meant foundations and a considerable amount of time in getting the establishments running.

The question of an external supply of electric current had certain points which required to be considered. If they had to obtain their current from an outside source they were entirely dependent upon that source, and in the event of a strike or some other civil disturbance they might find themselves very badly held up. He had experienced difficulty in that direction, and he very much favoured some independent source of supply of one's own. It might only be a partial supply, but it was an excellent thing to have as a stand-by.

Another question was the initial cost. If they adopted electrical driving for transmission, in some cases it meant an increase in the initial cost of the plant, but against that they had to set a certain value obtained from the plant. He was inclined to think that in some cases the absence of foundations and the ease with which plant could be moved for extensions or some other necessary alteration should be set against the initial cost of providing self-contained motors.

There was a further point he wished to make. He had had some trouble in the way of accidents connected with electrical transmission, but he was quite sure that any installation laid down now would provide against that. In those particular installations there had been no provision made against accident. The point was to have ready means at hand for shutting off the supply in case anything went wrong. He was sorry to say that there was a rather serious accident in one case, simply because the cut-off apparatus was not easily accessible.

In connection with large machine tools, he quite agreed that if they could not use a large machine tool continuously, it was not an economical proposition to adopt the individual drive, but, unfortunately, sometimes, especially for repair work in general engineering millwrighting, they had to take what work came along, and then they might be in the position that there was not readily accessible a machine tool of the nature required even within convenient distance where the work could be done. Therefore, there were circumstances in which it might be economical, even though the machine was not to be constantly employed, to have a large machine with its own motor available, because it enabled them to get the job done and avoided delay.

Another point occurred to him in connection with self-contained power plants, and that was the control of the lighting. It was very useful, if there were any night work or rush work, to have one's own power plant, because that also ensured current being available for lighting at the same time. Another point in favour of

electricity was the facility, especially in dealing with repair work, for example, automobile parts, with which small tools such as portable electric drills, grinders, etc., could be employed on the job, often with a considerable saving of time and labour.

MR. V. GARTSIDE thought this was one of the most interesting papers that had been presented to the Institution, from various standpoints, and especially from his own as a machine-tool maker. He appreciated quite a number of the remarks made by the author in regard to the application of motors for driving machine tools. As to when they should use independent motors for individual machines that was a very difficult matter to decide, as it depended a great deal upon circumstances. Personally, he should say that where a machine did not require more than 2½ h.p., grouping should be adopted, but even then it might be advisable to have one or two machines fitted with separate electric motors where they might have to run alone, such as for repair purposes. One of the advantages of electrical driving, from the machine tool user's point of view, apart from the convenience, was that it was a very simple matter to find out what a machine was actually doing. Where there were belt-driven machines it was often difficult to determine with exactitude what service they were giving, but with an electric motor on the machine, by means of voltmeters and ammeters, which were easily put into position, it could at once be seen whether the machine was doing its maximum work, or the work that it ought to be doing, or whether it was overloaded. Very often a machine was taking more power than was anticipated, and it was found that there was, perhaps, a bearing which was on the point of seizing. Therefore, he thought this was an excellent point and one of the advantages of the electric drive. He remembered a case of a very large lathe which appeared to be taking an excessive amount of power for some reason or other, and on investigation it was found that most of the trouble was due to the fact that the tail pin was not taking the pressure as it should do. It was decided to introduce a ball thrust, and the fact of introducing that ball thrust saved more in the cost of current than the machine attendant's wages.

A further point he would like to mention was the cost of running heavy grinders. At the present time there was a great controversy about grinding. He was not speaking of the comparatively small universal grinders but of the large grinders that were being introduced for grinding flat surfaces instead of planing. There were advertisements and accounts of these machines expeditiously removing considerable metal, but there was a large amount of power absorbed, especially when one heard of a firm putting 80 h.p. motors on these grinders. It might appear advantageous as far as first cost and also the actual wages cost were concerned, but it was also necessary to take into account the cost of the power, and this might be a great deal more than the difference between the old-fashioned method and the new one. If there were any direct information available on that point he would be very glad to receive it, because it was a matter in which he was greatly interested at the present time. With regard to the variable speed alternating current motor, this was certainly a welcome innovation for machine-tool makers. They had awaited its coming for some time. They had always been confronted with that problem, and still were at the present time. It would simplify the design of gear boxes when there was available

a satisfactory variable speed alternating current motor. There was one point he would have liked the author to dwell upon, and that was the switch gear. The author had spoken a lot about motors, but had said nothing about the switch gear, which was treated after the manner of countershafts. It was the last thing to be designed, and was often an abomination when it was designed. If there were any electrical engineers present, it was hoped they would be impressed with the necessity for giving a little more attention to the switch gear. He had occasion, when he was in France a month ago, to see a starting pillar that had been sent out from this country by a reputable firm. The apparatus was fastened together by small screws, and half of them were in the bottom of the case when it arrived, and the whole thing fell to pieces on being unpacked, owing to the vibration in transit.

Speaking of large machines not being fully occupied, that was a very difficult problem in a general engineer's shop. Sometimes it was necessary to have a big lathe for any job that was likely to come in, and they might not be able to keep it fully occupied. He knew of a case where his firm built a lathe to take the rotor-shaft for a turbine which was to be installed in a power station in Australia. That lathe was shipped there solely for repairs to that turbine. If there were no breakdown that lathe would not be used at all. That was an instance where there was a lathe remaining idle, but on account of the large turbine the lathe, which was fitted with an attachment for re-boring the casing if necessary, had to be retained in case of emergency, as it was out of the question to send the parts back to this country for repairs.

THE PRESIDENT stated that he had carried out a number of experiments in driving machines by independent motors. He was rather surprised that the author's experience had suggested that it was good practice to drive the machines independently when they took about 10 h.p. It rather depended upon the size of the machine. If it were a big planing machine, it would probably absorb more than 10 h.p., and with a large machine it was probable that the independent motor would be more economical; but take the case of a chucking lathe, say, a No. 6 Herbert. He had had twelve such lathes grouped, and any of them would require 10 to 12 h.p. when operating on the big face of, say, a large flywheel. By grouping these machines, however, he was able to drive them under maximum load conditions with a 30 h.p. motor. Let them imagine the total horse-power of all the motors if each machine had been fitted with its own motor; yet he was able to drive them perfectly satisfactorily with a 30 h.p. motor under the group system. The work was so arranged that certain machines would be taking the light finishing cuts and the others would be doing the heavy cuts, and by dividing the work up in that way it was found that the arrangement worked very satisfactorily. In the works with which he was formerly associated in Birmingham he arranged for a man to go round the shops to change the motors. The machines were engaged in the production of motor car parts, and the load factors changed and fluctuated. It was uneconomical to run the motors on light loads, and as he was working on three-phase current it was not safe to overload the motors seriously, and that brought up an interesting sidelight on the chain drive. He had to abandon chain drive altogether for line shafting with motors to facilitate the change. It was pos-

sible to change any motor in the factory during the dinner hour with proper tackle, and the viewer went round with his voltmeter and ammeter to determine which motors were overloaded and which were underloaded. A 20 h.p. motor would be changed for a 30 h.p. motor if the work required it, and changed back again a week later. A 15 h.p. motor might then be installed, and so on, and in that way he was convinced that he paid for the man's wages many times over. Current was purchased at a very cheap rate. The grouping of machines, however, depended upon the class of tools. In considering such a machine as the Hiloplane, where the motor had to perform functions other than the drive, other factors came into play, but for the normal type of drive he had found that with a suitable length of line shaft the motor drive was the best method of driving ordinary engine lathes and drilling machines such as were used in the tool room, and perhaps capstan lathes, etc. With regard to generating one's own current or taking it from the public supply mains, it was very nice to be able to generate on the works, but he preferred to let the cobbler stick to his last. If he wanted to make motor cars or telephones, he did not want to make electric current. Unfortunately, electric supply companies had monopolies, and unless the works had some pull they might have to pay excessively for their current when they purchased it.

As to the amount of power absorbed in grinding, he carried out some experiments a few years ago, and was not then worried about the cost of current. The main consideration was the cost of the abrasive wheels. He installed a modern grinder, and it absorbed about 12 h.p. when taking a cut. The aim was to grind instead of mill the surfaces of water pipes, cylinder tops, etc. The most suitable work was given to the machine, and, whilst it was true that the work was done very quickly and that about 25s. per week in wages was saved, it cost 35s. per week in wheels to save that 25s. Therefore, he did not trouble about the difference in h.p. between driving a milling machine and a grinder. If they could get current at 1d. per unit it was a convenience to be able to grind certain things such as the feet of benches or the tops of lathe standards, because they could use a cheaper casting that could not be milled, and even taking into consideration the cost of the grinding wheels it was cheaper in the end to grind.

He was very interested in what the author had said about welding. He wished he had described in greater detail the "Quasi" arc system. He was very interested in that, and if the author could inform them on the subject of the welding of thick plate with alternating current it would be very interesting.

Mr. J. R. Smith, in replying to the discussion, thanked the meeting for the cordial reception that had been given to the paper, which he felt it hardly deserved. Much of the subject matter in the paper could be read in the text books, but he had had an experience over a period of about thirty-eight years, both mechanical and electrical, and had drawn from that experience and had set out the facts in the paper. The President had mentioned the question of individual drive when the power for individual machine tools reached 10 h.p. He quite agreed with what the President had said on that point, that is, where they were driving machine tools needing approximately 10 h.p., such as engine lathes, turret lathes, capstans, etc., used on repetition work, it was a desirable practice

to drive them in groups. What he had in mind in putting forward the figure of 10 h.p. was the type of machine that absorbed 10 h.p., but on which a considerable amount of time was occupied in setting up the work. Generally speaking, however, in such matters one had to be guided by circumstances.

With regard to chain drives, the President said he had abandoned chain drives for line shafting, and that was quite right. There was no other means of driving shafting so efficiently as from a motor by means of a belt, unless they were prepared to go to the expense of a directly coupled motor, which he did not think anyone could afford to do. At the same time, the chain for short drives seemed to give very much better results than a belt, which is usually supplied with a jockey pulley to keep it tight.

As to the generation of power, there was a good deal to be said about that. It was an advantage to be able to obtain an alternative source of power in case the supply company became unreasonable. The cost of power was an important matter. He was perfectly certain that if the power supply people would only put their business in order and get down to rock-bottom prices by installing efficient plant, etc., they would get a considerable amount of revenue from factories where the load factor was reasonable. That would result in production costs coming down. The difficulty was well illustrated by the position in London, where there were a number of private companies supplying electric power, and he believed that in the Strand district the charge was still in the region of 8d. and the supply was at 100 volts. He need not pass any comments on such a position. The point was that it was necessary to straighten out this state of affairs not only for their own sake but for the welfare of the country as a whole. The manufacturers in France, Italy, Germany, and America are deriving their electric power in many cases from their waterfalls at a very cheap rate, probably about one-tenth the price that is being charged in this country. What chance, under such circumstances, did British manufacturers stand, apart from wages, in world competition?

He had only touched briefly on welding in the paper because it was felt that the paper was already too long, but he would like, at a later date, to give some additional data on welding if he might. At the present time the welding of heavy plates by means of strip steel and the carbon arc was in the form of an automatic operation, and he believed in the near future it would revolutionise the present system of riveting, especially for boilers and tanks. He understood there were several companies at the present time operating this system of welding, and they claimed to be able to produce a welded joint equal in strength to that of the double-riveted seam. If that were so, then it would mean a great deal. At the works with which he was associated there was carried out a large amount of welding, plates up to $\frac{3}{4}$in. thick being dealt with both by direct and alternating current, and it had been found that the welds were absolutely sound. Another point about it was that welding could be undertaken in very awkward positions. A case in point occurred quite recently, where a crack in a boiler would have involved great expense if it had been necessary to put a patch on in the ordinary way. By means of the arc welding process, however, this expense was saved, and a far better job was produced than by the patching

method. The boiler was working well, and the cost of the repair was about one-twentieth of what it would otherwise have been.

On the question of grinding machines, individual motor drive would probably be good practice in the case of a large grinder. The reason was that if an attempt were made to do high-speed work with countershafting, unless current was being obtained very cheaply, the cost of power was very high owing to the transmission losses. In other words, a very large amount of power was being absorbed to speed up the countershafting which should be expended in the final drive. What he referred to in the paper was that in every modern tool room of any magnitude there was a large number of internal and external grinders which operated probably at from 10,000 to 15,000 r.p.m., and these machines absorbed a tremendous amount of power in picking up speed, whereas if they were independently driven they could save 50 per cent. of that power.

He quite agreed with the remarks that had been made concerning switch gear, and as soon as the average electrical designing engineer realised the mechanical imperfections of switch gear the better for the user. He had seen some poor arrangements for switch gear. It was often overlooked that the operator of a switch gear frequently was a man who knew little or nothing about electrical matters, and in many cases did not know what would happen if he started the motor step by step or otherwise. Therefore, it was incumbent on the electrical apparatus manufacturers to produce a robust starter that the average man could not damage in five minutes. There was too much " follow my leader " in this country. Because the Cutler-Hammer people in America many years ago brought out a no-volt release which operated on the starting resistance, almost every maker in this country followed suit, but it is obvious that the no-volt release should be on the main switch and not on the resistance, so that the operator could not do the wrong thing if the circuit was not in order. Matters should be so arranged that the man could not operate his machine in his own way, but in its correct sequence. There is no doubt that a great deal of re-designing is still necessary as regards the ordinary switch gear. Another point raised had been the desirability of buying reliable motors and starters. It is patent that a considerable amount of money can be wasted in buying a cheap article. They should get good machines and then treat them fairly.

PROVINCIAL BRANCHES

PROVINCIAL BRANCHES

NEWARK-ON-TRENT BRANCH

THE first meeting of the above section was held at the Newark Magnus Grammar School on Monday evening, February 13th, when there was an excellent attendance. Mr. J. D. Scaife was in the chair, and the President of the Institution, Mr. Max R. Lawrence, addressed the assembly, and in the course of his remarks pointed out that the policy of the Council has been to decentralise as much as possible, and, therefore, to arrange for the establishment of local centres where sufficient support would justify that step. It was felt that there was a strong desire among engineers to meet together to discuss technical engineering production problems, and so give more time and attention to the subject than had hitherto been possible by other bodies of engineers.

There was no doubt that what the world needed in our present deplorable state of trade was a long spell of steady, hard production, to make up for the waste which occurred during the war.

As a great proportion, if not the whole, of this country's productions was more or less dependent upon the activities of mechanical engineers, production engineers had a most important part to play in developing economical manufacture to the fullest extent.

It was pointed out that the engineer needed opportunities to develop his ideas and to acquire the art of giving them ready expression, and no better medium for these purposes could be devised than attendance at such centres as those which it was proposed to form.

Each local centre would arrange its own programme of activities, elect its own committee and chairman, and apply to the main Council for any funds which would be necessary to defray the expenses of such meetings.

COVENTRY BRANCH

On the evening of February 14th, following the Newark gathering, a similar meeting was held at Coventry, when there was again an excellent attendance. The President occupied the chair, and set forth the advantages to be derived from membership of the Institution. Mr. R. V. Newton was appointed hon. secretary, *pro tem.*, and all enquiries relative to the Coventry branch should be addressed to him at 32, Sixth Street, Radford Estate, Coventry.

A short paper, entitled "The Position of the Foreman in Works Organisation," was presented on both occasions by the President, of which an abstract is given below.

During the war, stated the speaker, a great change had come over the life of the community, and now that actual hostilities were over we found ourselves in a queer world. Many of our cherished ideas have been rudely shattered, and the process of adjusting one's life to the new conditions is very uncomfortable.

One of the factors in the situation that was so difficult to understand was the alteration in all money values. Our currency had depreciated, and this had led to increases in wages to meet the higher cost of living, which in turn had caused the cost of living to increase, and so on in a vicious circle. Thus our common standards were all upset, and very few people realised what it all meant, or could see a clear way to the re-establishment of industry on a prosperous basis. Owing chiefly to the high rates to which wages have risen, and apparently to the greatly depreciated currencies in other countries which used to consume our goods, the cost of production has soared to a point at which our goods cannot be sold. This has resulted in unprecedented unemployment and thrown a further burden on the community in the form of unemployment pay.

As wages mount up, so it becomes necessary to economise labour, and this can only be done by employing better methods, which entails capital expenditure. To make this worth while, firms have had to concentrate on fewer types, and to produce them in larger quantities. As a result, our conditions have more nearly approached those ruling in the United States. It is a matter of no surprise, therefore, that we should have looked to that country for help, and to have copied some of its methods. Hence we hear of motion studies, planning departments, etc. There is, however, one essential difference between the conditions in this country and those in the States, quite apart from the contrast in markets, namely, that the supply of skilled mechanics is far greater in this country. This is an essential factor which ought never to be lost sight of when dealing with works organisation.

The procedure in the States is to employ a few highly skilled and highly paid engineers to devise machine tools, jigs, and other equipment in such a way that the unskilled labour available can be used to produce accurate work. This entails a relatively large capital expenditure, in justification of which large outputs are required. So it comes about that the production engineer has chief control in the workshops, and the duties of foremen and their relation to other departments are naturally quite different from those obtaining in the United Kingdom.

As our factories develop, various new officers and departments are installed, such as planning, labour, and welfare departments, works committees, and so forth. These all deal more or less with the work previously performed by foremen, and it is evident that the foremen's duties have undergone considerable change in recent times.

Instances were known where the works procedure in an extensive

organisation which was working successfully in the States had been injudiciously adapted and introduced to the works in this country, with the result that most of the engineering duties had been taken from the foremen, leaving their work more akin to that of policemen than was considered desirable or just.

It was quite unnecessary in developing these new departments to curtail in any way the authority of a foreman in what may be termed his technical engineering interests. After all, he was responsible for the output, and the speaker considered that he should have a voice in developing methods of manufacture.

The foreman should be the representative of the management in the works, and if he was at all times working in complete harmony with his chief, who is presumed to be competent, there would be less heard about the want of touch between workers and the management, and the need for works committees and other means for dealing with the human element would largely disappear.

All sub-division into planning, progress, rate fixing, viewing, labour departments, etc., could be developed through the foremen, and would in all probability operate far more successfully if they were in a measure subservient to, and treated as departments for, rendering assistance to the foreman.

The foreman should be trusted and be a party to all management decisions, and when his judgment has to be overruled he should thoroughly understand the reasons why this is done, and the power to overrule should only be vested in the works manager.

If a foreman is to be held responsible for the output of his shop, he must be in agreement with the manufacturing methods obtaining. At any rate, the foreman should have the opportunity of advancing his views, and if these are not in harmony with the methods adopted, he at least can have the satisfaction of knowing that he has had a voice in the matter.

As to the labour problem, it was suggested that the foreman requiring extra help should notify the labour department, who would do all the preliminary work, and having chosen, as they thought, suitable men, the final selection would rest with the foreman.

As to the dismissal of men, the opinion was expressed that the foreman should be responsible to some higher authority. If there were delinquents to be dealt with, the foreman could exercise his right of suspending them, which would allow of cases being investigated before drastic measures were taken. It was the conviction of the author that one of the weakest actions a foreman could take was to dismiss a man because of some fault committed. Drastic action, on occasion, would appear unavoidable, but it was wise to confine such measures to really exceptional cases for many reasons, not the least of which was that each time there was a change it resulted in a monetary loss to the firm.

The speaker, in summing up, urged that the foreman's position should be strengthened rather than weakened, despite the necessity

for the establishment, under modern conditions, of various new departments. Indeed, the foreman's capacity for stimulating increased production should be enhanced by these auxiliary departments, because, if those sections work harmoniously together, their goal must be increased output. The executive power directly responsible for such a desirable state of affairs undoubtedly rests largely in the hands of the foreman.

COVENTRY BRANCH

PRODUCTION METHODS IN A SMALL SHOP.

By Mr. E. V. DODMAN, M.I.P.E., Works Manager, Messrs. The Hillman Motor Car Co., Ltd., Coventry.

The subject of these notes will, no doubt, be of interest as opening up many points vital to efficient organisation. The method of the compilation of this short paper will lead us through a small works capable of producing, say, twenty-five cars per week.

It will be assumed that the works are well equipped with efficient machine-tools, but not of a number to warrant one particular job being allotted to any one machine, and that direction and foresight are necessary to compensate the disadvantages that obviously obtain.

To produce a light car on economical lines, overhead charges must necessarily be kept at their lowest. Many of these charges cannot vary, being of a constant nature, but if discretion be used and production maintained, such constant charges can be borne easily. It is essential, however, that non-producers be kept low in number.

With a small staff at one's disposal, the organisation has to be built to suit the circumstances. After selecting a competent staff, we venture to plan for a regular production on the basis already laid down.

The design is first and foremost, and in designing a light car much of its success depends upon the constructional material chosen. The firm designing a car to-day has to give the buying public an extraordinarily good production at a reasonably low cost. It is left to the public to make a manufacturer's reputation, and if he is fortunate to obtain one, his future productions are awaited with considerable interest.

Assuming a reputation has been gained for high-class workmanship, that standard has to be the basis of a maker's ultimate

existence, while the better the work the greater the difficulty in keeping at the pinnacle of fame. At the same time, one has not to disregard the unbalanced conditions of the financial world, and this a successful designer must always bear in mind, combining with it high efficiency and quantity production. So much for preliminaries.

Design of the production is submitted. It is built in the experimental department to rough drawings and specifications, working in conjunction with the tool-room drawing-office by passing along drawings to enable them to prepare for the necessary jigs and tools. This, of course, is done after consultation with the machine shop foreman regarding methods of manufacture.

While this important work is proceeding, the material specification would be prepared and issued to the purchase department, who would obtain prices and place orders for the necessary material in due time for delivery at a given date.

When the orders are placed, copies of such orders would be forwarded to the material control department, whose duty it is to see that sufficient material is delivered to meet the works' requirements and to arrange that the financial monthly burden of liabilities is comfortably balanced so that the manufacturer is not unduly embarrassed by having to pay for material which will not develop into sales within a reasonable time. This department, if thoroughly efficient, can effectively control the finance of any firm (large or small), and can rightly be looked upon as an essential economic institution. A further copy of the order will be sent to the goods receiving department, whose duty it is to see that all material delivered is entered daily, in triplicate, one copy of the goods receiving form going to the material control department for notification of delivery, and a copy to the purchase department to enable it to check invoices for quantities delivered and the price at which the order is placed.

An essential factor in obtaining satisfactory production is to see that all material delivered into a works is thoroughly examined. It might be argued that examination at this stage is unwarranted, but errors are in some works discovered due to defects in material at a time when, owing to the belated disclosure, the whole production is brought to a standstill—and everyone knows what that means at a busy period.

The finished product in this case may be designated—a small car built practically all of steel. A manufacturer's one and only consideration should be to protect the pocket of users against mechanical failure and breakdown, and the great point for all prospective owners of cars should be to make a careful study of the material from which a car is constructed.

A consideration of the employment of stampings, therefore, takes us to a process where steel can be used to the best advantage, while the varied treatments at present in use are able to give us

the desired strengths according to the duty assigned to any particular part. Another important section of a self-contained works, namely, the stamp shop, will now be briefly discussed. The first interesting study presents itself in a corner of the tool room where dies are being prepared to convert the bars and billets of steel into stampings of one form or another. It is surprising what can be done by a small battery of five hammers in the economical production of an extraordinary number of parts.

It is not claimed that the initial outlay on all stampings will prove cheaper than the malleable or steel castings from which the various parts are made, but when considering the amount of machining cost accruing on a casting which perhaps becomes scrap at a late stage, against the reduced cost of machining a stamping, and the minimised risk of scrap, the stamping process proves its worth. A typical piece is the differential box, the steel for which weighs 18lb.; material cost is 1½d. per lb., while labour to stamp is 9d., plus 100 per cent. departmental cost, including dies, bringing the total sum to 3s. 2d., against 10½lb. of malleable at 7¼d. per lb., making a cost of 6s. 4½d. Thus a saving in cost of material alone is effected of 100 per cent. Then again there is the advantage in strength, which after treatment, yielding 28 tons, gives the ratio of 2.5 to 1 stronger than malleable, yielding 16 to 18 tons.

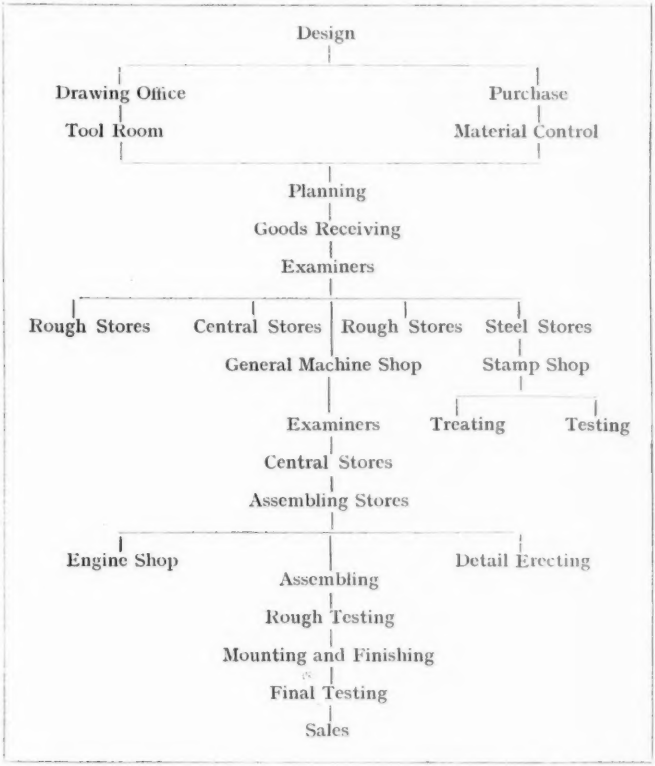
Another consideration is quickness of supplies, as stampings can be ready for use within two days of stamping, whereas the time for annealing malleable is a minimum of two weeks. Another point is the necessary setting of castings, which occupies further time, while stampings after clipping are put back into the die and set.

Another problem worthy of close consideration is failure on the road, and where castings are embodied in the construction the risk is great. Upon surveying the case of an axle sleeve [which was on view] many weaknesses might arise which are not visible to the eye at the completion of machining. For instance, the spring pad on the sleeve, with road shock as a principal experience, has been known to snap off, and this, of course, might prove disastrous when travelling at a reasonably high speed. Now taking the case of a sleeve built up from a steel tube and stampings this construction may be safely relied upon to sustain all those shocks so prevalent on our roads at the present time. In the opinion of the author, stampings in the long run prove their worth.

Stampings are ordered and supplied to a stores in like manner to bought out material, controlled by the material control department and released by them to meet the requirements of the shop from time to time. The method of release and issue will be touched upon a little later. Stampings are not considered as complete material in themselves and are not received into the stores until after heat treatment. For this process, a small modern heat treating plant is necessary through which all stampings pass in batches before going before the examiner, while the all-important factor in determining the proper strengths, etc.—

a test piece—accompanies each batch and must pass the proper test before the examiner releases the material to stores.

While all these operations are in train, the stores must not be overlooked—no small department in an efficiently organised works. The members of this section are busy through the stock record office, collecting all the necessary stocks to enable them, at the



appointed time, to issue their complete sets into the progress department, from where it commences to circulate.

Having settled all details with the planning department regarding the project to manufacture twenty-five cars per week, a decision as to the most economical manufacturing procedure has to be made. This is where the material control department functions as a policeman regulating traffic. This department will

issue release notes to the stores authorising release of fifty complete sets of material, when the stores immediately arrange all necessary issues to the machine shop, or other shops responsible for initial operations, while finished or bought out components go straight to an assembling stores. This represents two weeks' work as governed by the machine shop capacity to turn out fifty per fortnight, or twenty-five per week. While this work is going through, it will be apparent that there is another fortnight to enable the material control department to prepare and get material forward for another batch release of fifty, and the deduction from the foregoing is that cars can begin to be assembled within three weeks after receipt of rough material.

With reference to the progressing of the parts through the machine shop, this can be managed satisfactorily by two efficient men who are aided by the sectional examiners. By careful progressing an immense amount of transportation is avoided, and only six labourers are needed to serve the whole shop and progress.

There is a considerable advantage to be gained by the employment of sectional examiners. Defects can be detected earlier than if material had to await completion of an operation and be conveyed to a view room, and every operation can be examined by a small staff of four examiners.

After a period of two weeks, the finished machined work is passing into the general or central store whence it is issued, still under the release of the material control department, to the component or assembling store, who are only concerned with receiving the correct supplies of material for the sanctioned quantity. This store is divided into four sections with a man in charge of each, who will attend to the receipts from central stores and will issue the parts to detail assembling benches in quantities of twenty-five sets, which constitutes a week's work, thence continuing to issue weekly at the same rate. At the end of each erecting bench are racks to receive the finished components.

The chassis erectors are now able to work to schedule on the same basis as the remainder of the works, picking up the components from each rack, as the chassis moves forward. The chassis is next passed along to the electrician for wiring, then to the bonnet-making and painting sections, until finally it leaves the erecting shop to undergo an exhaustive test. Once out of the shop it never returns, as this would upset the production schedule, a corner of the test or running shop being reserved to enable any defects or failures on test, should they arise, to be remedied.

After testing, chassis would be cleaned down and handed over to the mounters, who are also responsible for twenty-five per week.

The car is now placed in the hands of the more skilled artists, in order to undergo a process of rubbing and colouring. It enters the paint shop unpolished and issues forth at the other end in all its glory of shining varnish. A few more touchings up and minor

adjustments, then the final examiner, who may be likened to the doctor, reports that a car is born.

Much depends for the efficient carrying out of the foregoing procedure on the *personnel* selected by the manufacturer. A choosing of the best brains for their respective spheres and the result is simple—but this is not all. One may hear—" What an expensive layout ! " The answer is that the floating stock to ensure a regular flow of twenty-five light cars per week can be efficiently handled and controlled at a moderate cost by co-ordinating the whole layout as shown by the accompanying chart.

If the author has been remiss in many matters relative to applied methods of manufacture he asks indulgence ; had he gone into these details the presentation of these notes must of necessity have been postponed.

COVENTRY BRANCH

On Tuesday, March 21st, 1922, Mr. H. A. Dudgeon presided at the third meeting of the session, when Mr. T. E. Pattinson (Member) read a paper on "Works Organisation" before 27 members and visitors.

The excellent nature of the paper promoted a good discussion, and the meeting formally thanked both Mr. Pattinson for coming down from London to read his paper and the Chairman for presiding.

COVENTRY BRANCH

REPETITION WORK IN THE ENGINEERING INDUSTRY.

By Mr. H. BRIGGS.

Foreword.

The last twenty or thirty years have witnessed a transition of the activities of the engineering industry from miscellaneous work to repetition work. Previous to the war the demand for such complicated engineering products as electric motors, pumps, and motor cars had resulted in their manufacture in quantity. During the war, however, although the shortage of skilled labour was acute, repetition methods enabled a huge output of munitions to be maintained.

Post-war reorganisation of factories has been based mainly on repetition lines, involving specialised plant and methods. Combinations of producers, previously competitors in miscellaneous work, have been formed. Each firm now manufactures one design only, on repetition lines, to be marketed by the group sales organisation. This specialisation results in lower production costs and a lower selling price, thus creating further demand. There seems to be no reason why this specialisation should not increase, as its growth is the result of the operation of a natural economic law.

In an engineering pupilage extending from 1914 to 1921 (with an intermediate period of war service in a technical corps) the author has had opportunity to study both the human and the economic aspects of repetition work. This paper embodies the content of his experience and reading on the subject.

Superficially, the growth of repetition work is economically, and hence nationally, sound. As at present practised, however, it menaces the principle of apprenticeship, and may eventually cause deterioration of individual and national character, stifling as it does the development of initiative and resourcefulness.

Payment by Results.

At the present day in England most repetition work is carried out under a system of payment by results. With this system the leading effect of the prospect of higher earnings replaces the driving force of the disciplinary foreman. A shop may therefore be said to run itself as far as volume of output is concerned. To ensure a definite standard of quality, a rigid and efficient system of inspection must be instituted. Inspection is usually carried out after each operation, and work scrapped by the machinist is not paid for.

The principle of payment-by-result work is the payment to the

worker of an amount over and above time rates in proportion to his output in excess of a standard.

The following systems are in use in England :—

(1) Piecework.
(2) Halsey-Weir premium bonus system.
(3) Rowan bonus system.

Under the piecework system a price is fixed on a job and the worker receives this amount for every one he completes, irrespective of the time taken. With the "Weir bonus system" a "time allowance" is fixed on a job. The extra time paid for as a bonus is usually half the time saved by the workman on this allowance. With the "Rowan system" the bonus is a fraction of the time taken, being

$$\frac{\text{Time saved}}{\text{Time allowed.}}$$

Piecework prices and bonus times are usually so fixed that an average man earns one-third above time rates. Where the bonus times are exceeded or where piecework earnings are less than time wages, the bare time wages are paid. In most shops, if one man frequently failed to earn bonus dismissal would result.

The Influence of Output on Cost of Production.

When day work is replaced by "result work," a large increase in output is usually attained, and when a new state of equilibrium has been reached the increase may be from 60 to 100 per cent. Whilst with the bonus systems direct labour cost is reduced at high rates of working, this does not hold with piecework. It is in connection with overhead charges that real economy results.

Production costs are usually divided into :—

(*a*) Material directly entering into the nature of product.
(*b*) Wages paid for work directly affecting product.
(*c*) Overhead charges or oncosts—*i.e.*, other expenses of manufacture.

In studying the incidence of oncosts, these may be divided into standing and running charges. Standing charges are such items of expense as rent, rates, taxes, interest, and depreciation allowance, which remain practically constant, being independent of the volume of output. Running charges cover plant and tool maintenance, supervision, lighting and power, etc. These charges have been found to vary approximately as the square root of the volume of output.*

On a unit of product the incidence of oncosts is lessened nearly inversely in proportion to the volume of output. As oncosts are often equal in amount to the direct labour cost, and are sometimes more, it will be realised how important is the volume of output from a given plant. Highly organised repetition work, coupled with a system of payment by results, therefore operates very strongly to secure low cost of production. The reduction of direct labour cost under repetition will be subsequently considered.

* Pearson on "Production Costs in Engineering." Journal of the Royal Statistical Society.

Effect of Repetition on Working Motions.

Constant repetition by the individual of a complicated series of motions enables their control to be relegated to the lower nerve-centres. When the performance of these motions becomes automatic, the action of the higher nerve-centres controlled by the brain is not required. The motions are instinctive and not reasoned, and as a reasoned motion naturally requires a longer time to take place, the basic cause of efficiency in repetition work is apparent.

The act of walking, an exceedingly complicated series of correlated motions, is an example of this. If every time a person walked each motion were to be dictated and correlated by the brain, the process would be slow and painful.

This repetition effect has also a direct application to working motions. The skilled fitter has cultivated that combination of motions and co-ordination of eye and hand that enable him to file flat without conscious effort. The tyro's attempt, however painstaking he may be, results in a curved surface.

Intervals between successive repetitions may vary considerably; it may be a matter of minutes or days. A fitter, for instance, may either assemble connecting rods to crankshafts, doing one every fifteen minutes, or may build an engine throughout, perhaps taking five days. As the assembling of an engine might require a thousand motions and the other job ten, a higher degree of automatism will be obtained on the shorter job, due to :—

(1) Fewer motions to master.
(2) Shorter time interval between repetitions.

This conclusion dictates the splitting up of jobs into small elements, each element to be performed by one man. The extent to which this specialisation is carried is limited only by the necessity for keeping an operator fully employed and by the cost of transport from operation to operation. To mitigate the evil of high transport costs the conveyor system has been successfully introduced.

Incidental Economies Effected by Repetition.

A worker will naturally tend, under a system of payment by results, to eliminate all non-working motions which are not essential. He will group his work upon his bench or near his machine so that it is readily accessible. Tools and gauges will be placed conveniently at hand. To save time he will make useful motions with both hands, simultaneously when possible. If a machinist, he will have greater opportunity of hitting upon the most suitable feeds, speeds, and shape of tools to suit his job and the machine on which it has to be performed.

As their cost may be spread over a large number of parts, expensive jigs and tools may be made to reduce operation times and special purpose machinery may be employed.

Raw and semi-manufactured material (stampings, castings, etc.) may be bought more cheaply in quantity. The total cost of stores, supervision, and general overheads may be lessened, although the percentage relation to direct labour cost may be actually increased.

One drawback of specialisation is that it entails carrying all the economic eggs in the basket of public demand for one article. If the demand fails, then heavy losses must be faced before production facilities can be varied to suit another type of product.

Examples of Repetition Work.

During his sojourn in the shops of an engineering factory the author carried out a series of experiments to determine the effect of repetition on the output of skilled men. Individual variation in temperament accounted for some disparity in the results obtained, but the cases cited below may be accepted as fairly representative of the average worker.

Sheet 1 (not illustrated) shows the effect of repetition on a job performed on a capstan lathe, particulars being noted on the sheet. It will be seen that the time to obtain jigs, tools and gauges, and to machine the first hub is comparatively long. When once the machine is set, however, the effect of repetition may be appreciated. This experiment was carried out over a period of nine working days, and the "Saturday" and "Monday" effects are quite noticeable. These will be discussed under the fatigue section of this paper.

A curve has also been plotted on the same sheet showing the average time taken for a hub reckoned on the total time taken for a batch of hubs. The importance of passing comparatively large batches of work through the shops is here seen. This effect of the "spread over" of setting up time is especially noticeable with semi-automatic and full automatic machinery. The author has found that with capstans on a certain class of work the setting up time is about five to eight times the operating time. With the same class of work on semi-automatics, however, the setting up time is about fifteen to twenty-five times the running time.

Curve 2 on Sheet 2 (not illustrated) shows an interesting comparison between a short machine operation and a short hand operation. The hand operation was the keying up of striking shafts with their forks and operating lugs. The machine operation was to rough out one side of a gear blank on a capstan lathe. The time reduction due to the repetition is seen to be two-thirds of the original time with the hand operation. With the machine operation, however, it is only about one-third.

American Methods of Intensified Repetition.

No study of repetition methods would be complete without dealing with the system of "scientific management." This movement, originated in America and still mainly confined there, has as its sponsors such men as F. W. Taylor, Gant, and Emerson. Whilst there are some detail differences in the three systems, in the main the principles are the same, and as F. W. Taylor has given the clearest exposition of his methods, his claims will be reviewed and discussed.

This scheme embodies the following:—

(1) The science of the work in hand to be carefully studied by experts, and the best methods of performing it determined.

(2) Careful selection of the workmen temperamentally and constitutionally best fitted to perform the work.

(3) The inducing of the workmen so chosen to submit unreservedly to whatever instructions and training are considered necessary.

(4) The training and helping of the operator to work according to scientific method.

Mr. Taylor stresses the fact that the worker, by reason of lack

of intelligence and education, is fundamentally unfitted to determine (1) for himself. To support his contention he instances 12 variables which affect the cutting of metals on a lathe, and which he contends must be considered before deciding the exact method of performing the work. These variables are:—

(1) Hardness of the work and other qualities.
(2) Chemical composition of cutting tool and its heat treatment.
(3) Thickness of shaving.
(4) Contour of cutting edge of tool.
(5) Nature and method of application of coolant.
(6) Depth of cut.
(7) Duration of cut (without regrind).
(8) Tool lip and clearance angles.
(9) Elasticity of work and tool producing chatter.
(10) Diameter of work.
(11) Pressure of chip on cutting edge of tool.
(12) Pulling power of machine and speed and feed ranges.

Functional Management under the Taylor System.

In this system the training and helping of the worker is not vested in one official, as in the so-called "military" system of management, but in a number of functional foremen as follows:—

(1) Inspection.
(2) Gang foreman.
(3) Speed foreman.
(4) Repair foreman.
(5) Time clerk.
(6) Route clerk.
(7) Disciplinarian.

The titles given to these functional officials are self-explanatory. In the event of friction occurring, the disciplinarian chief settles the matter. Under the supervision of these foremen the worker has every method and motion predetermined for him, and is required to submit entirely to his foreman's instructions. It is maintained that these instructions constitute the best method of doing the work. The definite claims of the system will now be given in the words of its originator.

Main Claims of Scientific Management.

(1) Scientific management improves and standardises industrial organisation and equipment, betters the training of workmen, and increases their skill and efficiency.

(2) Substitutes the rule of law for the arbitrary decisions of foremen, employers, and unions; and treats each worker as an independent personality.

(3) Increases productive output and improves the quality of the product.

(4) Sets each workman to the highest task for which his physical and intellectual capacity fits him, and tends to prevent the degradation and displacement of skilled labour.

(5) Stimulates and energises the workers intellectually and promotes their self-reliance and individuality.

(6) Raises wages and shortens hours of labour.

(7) Increases security and continuity of employment.
(8) Renders trades unionism unnecessary as a means of protection to a workman, prevents strikes, and removes causes of social unrest.

If these claims are justified by the results achieved by scientific management in practice, the golden age of industry has at last arrived. However, the views of those who work under the system do not quite coincide with these claims. The following is the official attitude of the Council of the American Federation of Labour towards the system in practice. An official inquiry into scientific management by the U.S. Government admits there is some ground for these opinions.

The Views of Organised Labour on Scientific Management.

(1) Considers the worker as a mere instrument of production and reduces him to a semi-automatic attachment to the machine or tool.
(2) Stimulates and drives the workers up to the limit of nervous and physical exhaustion and overspeeds and overstrains them. Tends to displace all but the fastest workers.
(3) Intensifies the modern tendency towards specialisation of work and is destructive to mechanical education and skill.
(4) Weakens the bargaining power of workers that they now wield through craft skill.
(5) Tends to lengthen the hours of labour; shortens the tenure of service; lessens the certainty and continuity of employment; leads to over-production and increase of unemployment.
(6) Condemns the worker to a monotonous routine and dwarfs and represses him intellectually.
(7) Increases the danger of industrial accidents, tends to undermine the worker's health, brings on premature old age, thus shortening his period of industrial activity.
(8) It is a reversion to industrial autocracy, which forces the workers to depend wholly on the employer's conception of fairness.
(9) It is unscientific in that it ignores individuality and habits, and is incapable of extensive application.

As these views constitute almost a complete refutation of the claims of scientific management, it is necessary to investigate the matter further. The difference of view is primarily one of standpoint. Taylor's claims apply to ideal scientific management run on disinterested lines. The workers' contention applies to a type of management installed, which only embodies those modifications immediately beneficial to the employer.

American Psychology.

Those who have enabled a new country like America to take a leading place in the engineering world are entitled to the respect and even admiration of engineers in older countries. However, there is no reason why such excessive adulation should be lavished on American methods as has recently been the case. The author feels that not only should the industrial aspect of scientific management be considered, but that its economic and psychological results should be realised at their true significance before its wholesale introduction into industry.

Before discussing this at further length a short study of American psychology may throw some light on the question. Professor William James, the eminent American psychologist, in an article preaching the "Gospel of Relaxation" to his countrymen, writes the following:—

"I suspect that neither the nature nor the amount of our work is accountable for the frequency and severity of these cases (*i.e.*, of nervous breakdowns). Their cause lies rather in those absurd feelings of hurry and having no time; in that breathlessness and tension; that anxiety of feature; that solicitude for results; that lack of inner harmony and ease, by which with us the work is apt to be accompanied, and from which a European who should do the same work would nine times out of ten be free."

Dr. Clouston, a prominent Scottish neurologist, says:—

"Americans wear too much expression on their faces; they live like an army with all its reserves in action. The duller countenances of the population of the British Isles betoken a better scheme of life, suggesting as they do stores of reserve nervous force."

Professor Munsterberg, a German psychologist, writes:—

"The appearance of unusual energy in America is superficial and illusory, being really due to the habits of jerkiness and bad co-ordination."

The Application of Scientific Management to Industry.

The author is more in favour of science in management introduced gradually than of a cut-and-dried system of scientific management introduced in two to three years. Perhaps after a term of years, the two lines, not being parallel, will eventually meet. The sudden projection of such a system on to industry could only cause dislocation and disruption. A *débâcle*, perhaps similar in intensity to that obtaining in Russia, where reformers impressed a system on a nation neither ready nor suited for it, might occur.

As yet the system has only really taken hold in the country of its inception. The author is aware of but three firms which practise these principles in England, viz., an iron foundry, a chocolate factory, and a cutlery works.

This seems to be due in the main to the following causes:—

(1) Adverse attitude of unions to the methods. Unions are stronger in England, where all workers speak the same language and combination is highly organised.

(2) A high degree of repetition is necessary for the full benefits of the system to be felt, and this rarely obtains in England.

(3) British psychology approves the principle of progress "from precedent to precedent" rather than by revolution.

The author believes that no definite pronouncement has been made on the subject by an official labour or trades union body in England, but imagines that the same attitude as that obtaining in America would be taken.

Undoubtedly unemployment, which the worker associates with high production, is the main industrial stumbling block in the way of cheaper production. This is not a bogey as some would have us believe; it is very real. "Over-production" does lead to short

periods of unemployment, although in the long run it is beneficial to all parties—the employer, the worker, and the consumer. The swing of the economic pendulum is slow, and it is difficult for the worker to take a long view of it on an empty stomach.

Industrial Fatigue.

It is only of recent years that scientific study of fatigue has been undertaken. Research was carried out by Dr. Stanley Kent in the earlier part of the war, and more recently by the investigators of the Industrial Fatigue Research Board. Even at the present day there does not exist a reliable test for fatigue which eliminates the will of the subject. It is surprising, considering how important this study is, that it has not attracted greater attention from those directly concerned in industry.

The following is Dr. Kent's definition of fatigue :—

" Physiologically, fatigue may be regarded as the expression of a condition of the neuro-muscular mechanism which tends to prevent further expenditure of energy when the supply runs low. The seat of fatigue is on the nervous rather than on the muscular side. It is not a direct expression of exhaustion of the supply of muscular energy, though probably dependent in great measure upon it. The appearance of fatigue is due to the action of a protective mechanism, similar to the safety valves of electric fuses, but, unlike these, acting when energy becomes deficient."

Hours of Work, Fatigue, and Output.

Repetition work naturally affords an excellent opportunity for judging fatigue, from the number of jobs turned out under different conditions. Under war conditions, this study was of great value, as output was in no way restricted, save by the fatigue of the operator. Trades union regulations were to a great degree suspended, and in most cases, apart from the financial gain, a sense of patriotism ensured that the maximum output was attained by the exertion of maximum effort.

Curve No. 3 on Sheet 2 (not illustrated) shows the influence of working hours on output, based on data obtained in an Industrial Fatigue Research Board publication.* It will be seen that the hourly output increased with shorter hours in such a degree as to make the total weekly output actually higher than before. This instance is fairly characteristic of hand operations. With machine operation and especially with automatic machinery, while the hourly output is increased, this is sometimes insufficient to equal the previous weekly output with a larger number of hours.

Though output is, under the above conditions, an excellent test of fatigue, something capable of a more instantaneous indication is required. The following methods have been used by Dr. Stanley Kent :—

(1) Complex reaction time (letter or colour test).
(2) Acuity of hearing.
(3) Acuity of sight.
(4) Blood pressure.

* The Speed of Adaptation of Output to Altered Hours of Work —H. M. Vernon, M.D.

With the first test—complex reaction time—fatigue shows its presence by a longer period being taken to recognise and respond to the test. As to the test for acuity of hearing, this is determined by registering the greatest distance at which the examinee can hear the tick of a standard watch.

Acuity of sight is determined from the greatest distance at which an examinee could identify standard letters.

The development of fatigue is in most persons accompanied by a rise in blood pressure, though this is to some extent modified by the diurnal variation. The investigator appointed by the Industrial Fatigue Research Board to develop a psychological test for fatigue reported that, owing to the difficulty of eliminating the will of the subject, he had been unsuccessful.

The possibility of using the wink reflex or changes in the pulse rate is now being considered. Sheet 4 (not illustrated) is a daily analysis of output for the present 47-hour week in the engineering industry based on observations made by the author. Considering daily output, it will be seen that the maximum is attained on Wednesday and Thursday.

Hourly output on most days is at its maximum about mid-day or a little before. On Monday, however, owing to the week-end rest, co-ordination is lost and the maximum hourly output is reached in the afternoon about 3 p.m. Output slacks off on Saturday morning, as it is only a 4-hour stretch and most of the workers feel they have " done their whack " for the week. Conversation about football prospects for the afternoon is brisk, and this naturally interferes with work. With this exception, the curve is really a fatigue curve.

On Monday and Tuesday we find the worker quite as fresh at the end of the day as at the beginning; on Wednesday, Thursday, and Friday, output drops off considerably towards 5.30.

Overtime and Fatigue.

Overtime forms a particular case of the general influence of length of the working day on the fatigue developed by the worker. It is usually resorted to in order to complete a rush or breakdown job, or to increase temporarily the productivity of a works without setting on more workers or laying down more plant.

Curve No. 5 (not illustrated) shows the effect of overtime over short periods, the sight test for fatigue being used. It will be seen what a marked recovery from fatigue occurs as a result of inserting a normal working day in a period of overtime. In working overtime it would seem advisable to introduce normal days as often as possible.

As regards overtime over long periods, Abbé made some observations on results obtained in this connection at the Zeiss Optical Works. He found that when the nine-hour day was increased to ten hours the total output increased temporarily, but after a week deteriorated, and by the third or fourth week the increase disappeared altogether.

The researches of Dr. Vernon show that in the case of a reversion to shorter hours, a period of from two to six months is required for equilibrium at increased hourly output to be attained. This is significant for, as he observes, it shows that the intermittent application of overtime over long periods is liable to reduce the speed of production permanently to the rate appropriate to the days when overtime is actually being worked.

Vocational Selection and Industrial Training of the Worker.

Apart from the basic fact that no system in itself embodies all the elements of human satisfaction, the author feels that there are two main causes of industrial unrest. First there are too many square pegs in round holes; and secondly, while accident determines in what hole they shall rest, they are forced to remain there without room for development.

As the worker leaves school, in the majority of cases at the age of 14, it is usually difficult to discover any suitability or aptitude for a particular trade. The determining factor appears to be the first job that offers. The more remunerative jobs are naturally sought after by the boy, as these give him a certain measure of early independence. Too often, however, the best paying occupations are "blind alley" jobs, and when a certain age is reached the young man joins the ranks of unskilled labour.

Unskilled labour is rarely completely absorbed by industry and is the first to be discharged in times of trade depression. Nothing is more destructive of the qualities of a good citizen than recurring periods of unemployment, and the transition from being unemployed to becoming unemployable is unfortunately too easy. A floating population of unemployables is a national menace, as it is the recruiting ground for the criminal classes.

The boy who is apprenticed, in the majority of cases, becomes a good and useful worker. However, there are far too many in the ranks of engineering workers who would do better in other walks of life, and whose inclusion in engineering is, in some degree, a loss to other industries.

Workers in other trades often adopt engineering work as a hobby, taking great pains and showing remarkable ingenuity. Useful work has recently been done by psychologists on vocational selection, and one can only hope that it may eventually be used to prevent national waste of character and energy, and to alleviate industrial unrest.

Under repetition methods it is becoming increasingly difficult for a broad apprenticeship to be afforded the young worker. Some might argue that, as the worker has only finally to do one type of work, training in that branch is all that is necessary. This would, of course, act as a stopper to valuable latent talent and would be a form of industrial suicide. Under present conditions it would seem best to afford the apprentice a good grounding in the tool room, before placing him in the production shop, where he is likely to remain.

The importance of technical education (if possible, part-time) cannot be over-estimated. There are as many keen brains in the workshop as in the great public schools, but too often the young engineer misses the chance of development which is the privilege of the student, a privilege which, by the way, is frequently too lightly regarded by those who have it.

Repetition Work and the Mentality of the Worker.

The average professional man, according to Dr. Macfie Campbell,* is engaged in work that was deliberately chosen, that appeals to him and corresponds to his native disposition. He gets joy from it, although in every kind of work there are periods of hard drudgery.

* *Journal of Industrial Welfare.*

Such periods, however, are rendered tolerable by the knowledge that they are essential to a successful career; the knowledge of the rewards —academic, social, or financial—that the labour may bring carries one through the period of drudgery. But joy in work, which belongs to the skilled craftsman or the professional worker, is a luxury that many other workers do not have under repetition methods. The nature of the work is usually such that there is little possibility of its giving satisfaction to anyone with average aspirations.

It is the author's experience that this constitutes, with a large number of workers, a serious repression of mentality. Once he has mastered the particular phase of repetition work upon which he is engaged, he is condemned to a monotonous routine during working hours, only relieved by what outside interests he may form.

Release from this monotony by promotion is rare, as the proportion of foremen and charge hands is small compared with the number of thoroughly experienced workers under their control. This repression during working hours is shown by the natural reaction in the craving for excitement which animates the working classes during their leisure hours. In some this results in betting and insobriety, in others in sensational newspapers, or the picture palaces may meet this need.

However, the striving for self-expression may take another turn. Lord Askwith traces a large proportion of industrial unrest to those workers who, unable to find self-expression in their work, turn to the wider field of labour politics and extremist propaganda. There are certain social doctrines, highly desirable in themselves, but entirely incapable of immediate realisation at the present stage of evolution, which make a strong appeal to the worker. A torrent of abuse and destructive criticism is showered on the existing social order by these cheap orators, and the seeds of unrest, sown on fertile ground, soon germinate.

Suggested Remedies for Mental Repression.

In the present state of industry we are naturally primarily concerned with restarting the factories, but this question of joyless work is one which will certainly loom large in the future.

Dr. Rothenau, one of Germany's leading industrial magnates and ex-Minister for Reconstruction, has published a book called "The New Society," dealing with labour unrest. "The root of the trouble," he says, "lies in the conditions of labour. Mindless and soulless work no man can do with any joy.

"The terrible fact about the mechanisation of industry is that productive work, which fills more than half of each man's waking day, is by it made hateful. It degrades the industrious man, thrilling with energy, into a work-shy slacker."

As a remedy Dr. Rothenau suggests "interchange of labour." By this he means "that every employee engaged in mechanical work can claim to spend a portion of his working time in intellectual employment." Otherwise, he says, we shall reach a state of society comparable to hell.

Other remedies not so sweeping in character as Dr. Rothenau's, which might mitigate the evil, suggest themselves.

(*a*) Periodical movement of a worker from one class of work to another—of course in his own trade.

(*b*) Periodical movement of a man from one firm to another.

(*c*) Work made more interesting by a "publicity department" in the works. At present the worker is usually ignorant of the destination of the part he is working on in the finished machine, and its precise function. The author has found that the majority of workers are keen to get hold of this sort of information, and has personally answered many queries of this nature.

(*d*) Gradual reduction of working hours, so that the time spent on monotonous work would be offset by greater leisure. Improved general education would enable additional leisure to be properly utilised.

The author admits that the present state of industry precludes the introduction of any section of the foregoing, as each section, if embodied, would call for expenditure with no immediate economic return.

Conclusion.

As the scope of these notes is wide, the conclusion will embody a measure of recapitulation by paragraphs:—

Specialisation in manufacturing engineering is increasing as a result of the operation of economic laws. The formation of groups and combines which has taken place is, within limits, beneficial to the consumer, as it avoids costly overlapping of effort and material. The large concern, however, tends to abolish personal relations between management and workers.

An efficiently administered system of payment by results is of benefit to both employer and employees. With increased output, low cost of production and high wages are not inconsistent.

To obtain the full economy in repetition work, jobs must be split up into small elements, each to be performed continuously by one man.

Associated with repetition and manufacture in quantity, there are important indirect economics, concerned with purchasing of raw material, plant, and administrative expenses.

Instances of repetition work show a great economy of working time due to the development of automatism and to a species of personal scientific management practised by the worker.

The principles of scientific management as a system are sound in theory, but the claims for it in practice ignore the weaknesses and shortcomings of human nature.

The views of organised labour in America have laid bare and exaggerated the weak spots of the system in practice.

A comparison of British and American psychology shows why scientific management as a system has not obtained a hold in England. The gradual introduction of the methods of Taylor (amplified by work on the lines of Gilbreth on motion study) will take place as the result of the more conservative British policy of science in management, as the methods are fundamental.

The study of industrial fatigue has not received the attention and support it deserves, from either industry, Government, or science. Up to the present, research indicates that long hours do not of necessity mean large output. With long hours the percentage of lost time is invariably increased and hourly output reduced. The intermittent application of overtime over long periods may cause a permanent reduction in hourly output.

Psychological tests as a means of vocational selection should be developed, and form the basis of a choice of occupation.

Repetition methods at present cause intellectual repression of the worker, and this effect will increase as time goes on. As this is the main cause of industrial unrest, it may result, unless remedied, in social upheaval.

SPECIAL PLANT ORGANISATION.

By Mr. B. W. DAWKINS.

There are scores of different trades, from jam-making to ship-building, which require special plants. Each one necessitates an entirely different arrangement for the flow of internal business. Volumes could be written of the various trade plants, and thus the title given to these notes is rather sweeping.

The works organisation to be described is one the writer devised for a works manufacturing a certain valve used on land, locomotive, and marine steam generators. A similar system might readily be applicable to any other works engaged in the production of a specialised article, say, for example, a gear box.

The reason for not putting forward details of some scheme that is actually employed in an existing works and in dealing with something which is "in the air" is explained as follows. Although the scheme to be outlined may resemble in some respects the method of organisation of some existing works, it is new, so far as the writer is aware. The suggested works procedure is therefore entirely unbiased by any organisation the writer has come in contact with, and thus the paper may contain some useful suggestions for those concerned in works management.

The system is outlined under the several headings given below.

Standard and Stocked Products.

An order received from an agent or representative at the sales office is recorded very simply in order to determine the value of specific areas or territories. For example, such returns would form a valuable guide as to whether a certain area warrants two or more representatives or whether one would suffice. In some cases it might be shown that a given district could with advantage be merged into an adjacent one. Such records are of use as a means of ascertaining the value of advertising media. From the sales office the order is passed to the head office (works), where, of course, all accounts are kept.

Many orders will doubtless be received at the head office from firms—particularly those of old standing on the company's books—as there are many business houses who appear to think that they receive better attention by eliminating all intermediate sales offices. Where this procedure is adopted by a customer an order is made out at the head office, a copy being sent to the sales office concerned in order to keep their records correct. In all cases the contract number is given by the head office.

A corresponding order is placed with the finished stores, the delivery of the articles being made in accordance with the dates

appearing on the order. What follows is more or less of a routine nature—the dispatch department passes the copy of the delivery note to the finished stores office, who cross off their chart the delivery made, and pass the same copy to the head office for the usual invoicing purposes.

Special Designs.

When a customer desires a special design of valve or a valve coming between the standard sizes, it is treated as a special contract. The inquiry is answered to the effect that the designing department will deal with the matter until a design fulfilling the stipulated requirements has been evolved. Correspondence is then taken up by the chief engineer direct with the customer. When the question of design is settled and has been discussed and approved by the "House of Lords" (to which reference will be made later) and also by the customer, the general manager is informed to that effect and of the price. It is then his business to negotiate with the object of securing the contract. If successful, the order is passed through to the works in the manner already described.

All special contract numbers are given by the drawing office, these numbers corresponding to the drawing numbers of the general arrangement of the jobs. Thus the works, on receipt of the order for any special contract, have merely to requisition drawings for such and such a contract number.

Finished Stores.

The finished stores are obviously where the standard articles are stocked. With the particular article in the author's mind there are ten standard valves—four land, two locomotive, and four marine steam generators.

It is the duty of the finished stores to order from the works the valves they are required to deliver in three weeks from date. As long contracts are made by weekly deliveries, for the twelve weeks ahead the total weekly deliveries are averaged so that orders on the works make more or less even weekly demands. Thus the stores receive more one week than they require, and less some weeks later. Separately, a predetermined number of each standard valve is kept in stock for orders calling for immediate delivery. As this stock falls, other articles are ordered from the works, these orders being placed immediately any articles are drawn from the stock. Spare parts are stocked in equal number to the reserve stock of complete articles. All orders from the finished stores are placed at the works manager's office. The requirements of the stores being averaged, in case of lack of orders, requisitions may be placed with the works until the accumulation of stock is ten times the number in the reserve stock.

Works.

An order having been received at the manager's office from the finished stores, work cards are prepared and delivered to the foreman of each operation, who fills in the name of the operator and the machine number. It is the duty of the production controller, who issues these cards, to track each job and to see that it is delivered to the inspection room in a period corresponding to that fixed by the rate-fixer. The machined parts with the operator's

work card are delivered to the inspection room, where all parts are stamped with his number before the operator departs. The operator then returns his card to his foreman for another lot of work, and the inspector, having examined the parts, fills up a card. On the delivery of the parts to the erection shops this card is sent direct to the works manager's office, and from these reports records are kept of the percentage of scrap made by each operator throughout the works. The scrapped material is sent to the material stores, where it is disposed of in the usual fashion. Parts which have been passed are delivered to the erection shops, where they are "married up" and erected. An erector having finished a batch of valves has his number stamped on each one by his foreman. The valves, having been passed on to the final test shop, are each one stamped with the number of the tester. They are then delivered to the finished stores. Throughout the progress in the works it would be practically impossible for an operator to be blamed for the fault of another operator.

The stamp shop and foundry are treated as outside contractors, and they deliver all material to the works through the goods inward dock. Each of these departments receives an order, as would a contractor, from the head office, and definite delivery demands are made. Since, however, these departments only supply the one plant, and the weekly demands being known within close limits, the shops are, of course, laid out for a given capacity.

Material Stores.

The works, knowing approximately what their demands will be for several weeks ahead, advise the material stores. These stores are responsible for ordering through the head office the necessary material to meet requirements, 5 per cent. over stock on the "heavies" being allowed to meet any likely demand for rush extras. Materials all enter by the goods received department, including goods from the stamp shop and foundry, at the same time samples being forwarded to the laboratory. None of the material entering the stores is issued to the shops until the head storekeeper has received a report from the laboratory that the particular material is up to standard in quality. The material stores issues the required steel, castings, or stampings to cover the work set out on the operator's work card, machine scrap and material scrap being returned in exchange for new material. As the material stores are in possession of figures showing the number of valves to be produced for several weeks ahead, and knowing the material required to satisfy the needs of the works, they in turn average their requirements and also level out the demands. In ordering material through the head office the material stores make clear the amount to be delivered weekly.

Drawing Office.

This department need not be described in any detail, since the author believes his ideas here are commonly accepted practice.

So far as actual drawings are concerned, the author has found in his experience that it is an advantage to use one size of sheet only, that being Double Elephant (40in. by 27in.), this size being divided to accommodate several sizes in this manner:—the sheet is divided in two, giving 20in. by 27in., the drawing number being

followed by /2, so that, for example, there would be a number 2081/2; it is again divided by two, giving a quarter of the large sheet, the drawing number being followed by /4; if it is once more divided it results in a sheet 10in. by 13½in., the drawing number being followed by /8. These sizes cover all requirements. It will be seen that it is possible to have four drawings of the same number but of different index, viz. :—40in. by 27in., 2081/1; 27in. by 20in., 2081/2; 20in. by 13½in., 2081/4; 13½in. by 10in., 2081/8.

All dies, patterns, tools, and jigs relating to a part on any drawing sheet are stamped with the drawing number. Also, all parts are stamped with the drawing number, so that any particular part requiring replacement may be readily requisitioned by quoting the number stamped on it.

The author has been more than once impressed with the necessity for a drawing office "House of Lords," having had experience of a number of "howling" examples of the inability of the designer to imagine himself machining, moulding, or pattern-making the job he had on the board before him. On several occasions the author has seen parts designed of a contour extremely difficult to machine when a more simple design might have been evolved without in any way interfering with the efficiency and proper functioning of the particular element. This is noticeable in many cast and stamped parts.

For some time the author was a colleague of a designer who had not spent a single day in the works, and it was common for that designer to draw out parts which were almost impossible to machine. It is for this reason that the author advocates, in the first place, that no man be engaged as a designer or draughtsman of machinery unless he has had a thorough training in the works. Those holding leading positions should certainly have spent a short time in the pattern-makers' shop and a fairly long period in the floor section of the foundry.

Recently the author had the opportunity of seeing an engine bearer for an aeroplane. This was cast in malleable iron, the greater portion of the casting being $\frac{3}{16}$in. thick. It was a box arrangement, with three strengthening webs inside, the only outlet from this cavity being two circular holes about 1¼in. diameter. This was all there was on which to stand the four cores necessary to making the cavity in the casting. It took one man approximately six to seven hours to make the mould and about two hours for three men to lay the cores, which were, when being placed, dangling on pieces of string, and the slightest slip on the part of any of these men would have completely scrapped the job. Possibly the complete part weighed about 8lb. to 9lb. This appeared to the author to be one of those cases where, with a little more thought and a little closer co-operation with the foreman moulder, a more sane design without impairing efficiency might have been evolved.

Buying.

The author here makes a plea for the technical buyer. By this is meant a man who has spent a certain amount of time in the works in order that he may thoroughly understand what he is buying. At the same time, it is not wise to appoint a man who has spent so much time in the works that the machinery around him has, so to

speak, robbed him of his business or commercial acumen. Conscientiously some buyers do their very best to save for their directors in all directions when buying, but in many cases in their zeal they defeat their object. As a case in point, the author requisitioned some milling cutters of a well-known make, the price being 21s. 9d. each, and ten were ordered. On looking up the catalogue and so forth the buyer found that he could procure the same size cutters of another make for 20s. 10d., saving, as he thought, 9s. 2d. on the total. These cutters proved quite useless for the material they had to cut. We had previously used the more expensive cutter, which had stood up to the work for a remarkably long period. The buyer had been urged, of course, to save every penny possible, whilst the works had been enjoined to maintain a high standard of efficiency and excellent workmanship. The result was that the works' officials exerted every effort to secure good tools with which to turn out good work. In the case of these cutters we did eventually succeed in having the unused ones returned and replaced by better cutters. The actual cost of the correspondence and the carriage on the two lots of cutters amounted to just over 14s. In an effort, therefore, to economise, a loss was sustained. If these small losses are repeated the cumulative effect is considerable in twelve months.

Sales.

Whilst sales representatives should possess a considerable amount of commercial ability and should be able readily to quote prices, discounts, and so forth, it is highly desirable that they should be trained engineers. By having these qualifications they are able to enter the designing room or the shops of a prospective customer and answer all questions of a technical nature which may be put to him. He will also be able to make suggestions as to designs that would meet requirements, and generally be of assistance in solving the customer's problems.

The sales manager might be a purely commercial man, and need not necessarily be an expert on the technical side. His chief duty lies in the settling of sales policy and the many details which arise in connection with the work of representatives in the various districts. His advice will also be valuable in connection with the advertising policy to be followed in trade journals, etc.

The foregoing contribution is the author's attempt to outline a system of plant organisation which he believes will meet the exigencies most commonly encountered in a concern of moderate dimensions.

LIST OF MEMBERS

LIST OF MEMBERS

Armitage, H. C., 43, Central Avenue, Northfield, Birmingham.
Atkinson, H., 78, Queen Victoria Street, E.C. 4.
Attwood, W., 26, Bedford Row, W.C. 2.

Ball, E. D., 19, Sellons Avenue, Harlesden, N.W. 10.
Bell, J., 81, The Grove, Wandsworth, S.W. 18.
Bingham, J. H., Messrs. F. N. Pickett et Fils, Saigneville Par St., Valery, Somme, France.
Blakey, J., 10, St. James Street, Paisley.
Bloomfield, G. F., Messrs. Martinsyde, Ltd., Maybury Hill, Woking, Surrey.
Bond, E. T., Courtald Road, Braintree, Essex.
Boothroyd, P. W., Messrs. Telephone Manufacturing Co. (1920), Ltd., Martell Road, S.E. 21.
Boucher, F. M., 32, High Street, Redbourne, Herts.
Bryan, A. C., Messrs. Associated Equipment Co., Ltd., Blackhorse Lane, Walthamstow, E. 17.
Buchanan, J. W., 5, Argyle Gardens, Upminster, Essex.
Butler, A., 19, Thornton Avenue, Chiswick, W.
Butterworth, H., Messrs. A. Butterworth & Co., Ainsworth Street, Rochdale.

Chick, F. W., The Engineers' Club, Coventry Street, W. 1.
Cook, H., Messrs. Arrol-Johnston, Ltd., Dumfries.
Crooke, P. S., Messrs. Humber, Ltd., Humber Road, Coventry.

Davey, A. T. H., 6, St. James Square, Holland Park, W. 11.
Dodman, E. V., Messrs. Hillman Motor Car Co., Ltd., Pinley, Coventry.
Dormer, W. F., c/o Messrs. George Clare & Co., Ltd., 8, Wormwood Street, E.C. 2.
Doxsey, F. H., 46, All Saints Road, Wolverhampton.
Dudgeon, H. A., 12, Manor Road, Coventry.

Eastwood, G. W., Messrs. Arrol-Johnston, Ltd., Dumfries.
Eden, Capt. G. M., R.A.S.C. Mess, Bulford Camp, Wilts.
Edwards, J. L., 27, Holly Bank, Kersal Road, Prestwich, Manchester.
Ewing, R., 8, Graham Street, Barrhead, Renfrewshire.

Fanthorpe, H. H., 47, Greenwood Road, Dalston, E. 8.
Fisher, W. L., 6, Ormond Road, Richmond.
Ford, W. A., Messrs. Rolls-Royce, Ltd., Derby.

Gair, D., Messrs. J. G. Jackson, Ltd., Pollokshaws, Glasgow.
Galbraith, Capt. J. A., Messrs. Crossley Bros., Ltd., Openshaw, Manchester.

Gartside, V., 34, Victoria Street, S.W. 1.
Goodfellow, J. W., Messrs. Singer & Co., Ltd., Coventry.
Grafton, H. O., Messrs. J. G. Jackson, Ltd., Pollokshaws, Glasgow.
Greenhill, H. A., Northampton Polytechnic Institute, Clerkenwell.
Guyler, A. F., 48, Imperial Road, Beeston, Notts.

Hales, G. H., Messrs. Drummond Bros., Guildford.
Hammond, C. F., 1, Lyndhurst Gardens, Hampstead, N.W. 3.
Hey, G., Messrs. Jigs, Ltd., 24, Peterboro' Road, Parson's Green, S.W.
Hill, H., 397, Chapter Road, Willesden Green, N.W. 2.
Honer, H. E., 273, New Cross Road, S.E.
Hossack, E. F., c/o Messrs. North British Lifting & Moving Appliance Co., Ltd., Cowlairs Road, Springburn, Glasgow.
Hurrell, R., 12, Chester Street, Coventry.
Hutchings, R. R., 22, First Avenue, Acton, W. 3.

Jardine, R., 333, Lepton Lane, Forest Gate, E. 7.
Jones, W. T., Messrs. A. Ransome & Co., Ltd., Stanley Works, Newark-on-Trent.
Joyce, Vernon, 22, Heath Road, Undercliffe, Bradford, Yorks.

Kenworthy, J. T., Messrs. Tilling-Stevens, Ltd., Maidstone.
Kitchen, H. E., 34, Marlboro' Road, Shipley, Yorks.
Knight, M., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.

Lambert, A. J., Messrs. C. A. Vandervell & Co., Ltd., Warple Way, Acton, W. 3.
Lawrence, Max R., Messrs. Sterling Telephone & Electric Co., Ltd., Sterling Works, Dagenham, Essex.

MacGregor, G., Messrs. S. Smith & Sons, Central Works, Cricklewood.
Mansfield, Lt.-Col. W. R., 149, Gleneldon Road, S.W. 16.
Marles, H. F., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Marston, H., " The Rosary," Benhill Avenue, Sutton.
Mathias, R., 9, Fordingley Road, Maida Vale, W. 9.
Meeson, W. P., Messrs. Arrol-Johnston, Ltd., Dumfries.
Mitchell, R. J., " Westfield," Upton Road, Slough.
Munro, A. A., Messrs. Synthetic Ammonia & Nitrates, Ltd., Billingham.

Newton, R. V. W., 13, Holland Road, Coventry.
Norman, G. L., Messrs. Drummond Bros., Guildford.
Norwood, H., 60, Manor House Lane, Holm Slack, Preston.

Pattinson, T. E., Messrs. Associated Equipment Co., Walthamstow, E. 17.
Pearce, R., Messrs. D. Napier & Son, Ltd., Acton Vale, W. 3.
Pettit, C. S., 18, Great Avenham Street, Preston, Lancs.
Pomphrett, R. A., Messrs. Willys-Overland Crossley, Ltd., Heaton Chapel, Stockport.

Reynolds, J. G., Messrs. D. Napier & Sons, Ltd., Acton Vale, W.
Rice, J. W., c/o Messrs. Keighley Gas & Oil Engine Co., Ltd., Keighley.
Richardson, A. C. J., M. & M. Club, 3, London Wall Buildings, E.C. 2.
Richardson, C. G. H., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Robson, C. P., Messrs. Robsons, Ltd., Fazeley Street, Birmingham.
Robson, S. B., 200, Franklin Road, King's Norton, Birmingham.
Ronald, J., c/o Messrs. Napier & Sons, Ltd., Acton, W. 3.
Rose, S., 11, Lindum Road, Lincoln.
Rossiter, C. F., Messrs. Record Engineering Co., Ltd., Tutbury, Burton-on-Trent.

Saunders, W. C., Messrs. Power Speciality Co., Rusham Road, Egham, Surrey.
Scaife, J. D., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Shaw, F. D., Messrs. David Brown & Sons, Ltd., Huddersfield.
Shaw, P. A., Messrs. Hillman Motor Car Co., Ltd., Pinley, Coventry.
Skipper, C. T., 37, Dudley Road, Grantham, Lincolnshire.
Sloan, K. M., 2, Crown Mansions, Partickhill, Glasgow.
Smith, J. J., Messrs. Lucas Electric Co., Ltd., Gt. King Street, Birmingham.
Smith, J. W., 64, Thurlly Road, Wembley, Middlesex.
Smith, N. G., Messrs. Accounting & Tabulating Corporation of Great Britain, Ltd., Thornton Heath, Surrey.
Stevenson, D., Messrs. G. W. K. 1919, Ltd., Cordwallis Works, Maidenhead.
Stoat, P., 78a, Salisbury Road, Kilburn.
Storey, W. H., Messrs. Accounting & Tabulating Corporation of Great Britain, Ltd., Thornton Heath, Surrey.
Sykes, T., Messrs. Humber, Ltd., Stoke, Coventry.

Tatlow, H. E., Messrs. Ruston & Hornsby, Ltd., Motor Works, Lincoln.
Thomson, G. W., Messrs. Blackburn Aeroplane & Motor Co., Ltd., Olympia, Leeds.
Tilley, H. B., Huntspill East, Broomfield Road, Chelmsford.
Toy, A. W., Cedarholme, St. Margaret's, Richmond, Surrey.
Treasure, E. J., Hearsall House, Hearsall Lane, Coventry.

Verrier, W. J., Messrs. English Electric Co., Willans Works, Rugby.
Voiles, O. M., c/o Messrs. Chelsea Motor Building Co., Ltd., 164, King's Road, Chelsea.

Waring-Brown, R., 8, Shalimar Gardens, Acton, W. 3.
Watson, J. M., 172, Lancefield Street, Glasgow.
Whittaker, J. W., 1, Neeld Crescent, Hendon, N.W. 4.
Wooster, R. D., 3, Hillcrest Road, Acton, W. 3.

Young, J. G., 20, The Grove, Wandsworth, S.W. 18.
Youngash, R. H., Messrs. Austin Motor Co., Ltd., Longbridge Works, Northfield, Birmingham.

Associate Members.

Archer, R. H., Wolviston, nr. Stockton-on-Tees.

Barrand, H. B., 11, Friars Road, Coventry.
Belcher, E., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Body, A. D., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Bone, H. J., 6, Redcote Street, Moston, Manchester.
Brinjes, G. N., 146, Crouch Hill, N.8.
Broadbent, J. W., Messrs. John Fowler & Co., Steam Plough Works, Leeds.
Butterworth, A., Junr., Messrs. A. Butterworth & Co., Ainsworth Street, Rochdale.

Crowther, W., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.

Dixon, E. A., 53, Victoria Street, S.W.1.

Eld, P. W., Messrs. Hillman Motor Car Co., Ltd., Pinley, Coventry.

Franklin, W. R., Messrs. The Coventry Chain Co., Ltd., Coventry.

Harvey, A. E., 24, Poplar Mount, Belvedere, Kent.
Henderson, G. B., 33, Osborne Street, Radnor Park, Clydebank, Scotland.
Holister, F. D., Messrs. Coventry Chain Co., Ltd., Coventry.

Jones, H. H., 76, Gordon Road, Ilford.

Lane, C. W., c/o Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.

Mantell, H., 47, Jesmond Avenue, Wembley, Middlesex.
Marston, J. C., c/o Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Moore, J., Messrs. Associated Equipment Co., Ltd., Blackhorse Lane, Walthamstow, E.17.

Nicholls, C. H., c/o Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Niekirk, P. B., Messrs. Associated Equipment Co., Ltd., Blackhorse Lane, Walthamstow, E.17.
Northey, C. B., 27, St. Mary's Road, Harlesden, N.W.10.

Parker, Q. F., Messrs. Aster Engineering Co. (1913), Ltd., Wembley, Middlesex.
Parkin, G., c/o Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Puzey, W. E., c/o Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.

Renshaw, W., c/o Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Revill, W. E., Messrs. Revill & Son, Manufacturing Engineers, 337, Albany Road, Camberwell, S.E.5.
Rowlett, H., Messrs. John Fowler & Co., Ltd., Steam Plough Works, Leeds.

Scott, A., c/o Messrs. Birtley Iron Co., Birtley, Durham.
Steel, C. O., c/o Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.
Sutcliffe, W. H., c/o Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.

Thacker, G. A., Messrs. The Coventry Chain Co., Ltd., Coventry.

Wilford, J. P., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.

Associates.

Banyard, C., 65, Abbot Street, Doncaster.
Beauchamp, A. E., Messrs. Broom & Wade, Ltd., Engineers, High Wycombe.

King, G. T., Messrs. Ransome & Marles Bearing Co., Ltd., Stanley Works, Newark-on-Trent.

Luke, C. H., 1, Elm Road, High Barnet.

Waudby, R., 35, Broomhall Place, Broomhall Park, Sheffield.

Graduates.

Bushnell, B. F., 164, King's Road, Chelsea, S.W.3.

Hanman, J. L., Eastgate, Gloucester.

Montgomery, G. A. T., 17, Chandos Road, Causeway, Staines.

Nash, F. J., Clock House, Shackleford, nr. Godalming, Surrey.

Patrick, C. C., Messrs. Aster Engineering Co., Ltd., Wembley, Middlesex.

Rogers, A. T., 18, Templemore Avenue, Ballymacarrett, Belfast.

Affiliated Firm.

Messrs. Alfred Herbert, Ltd., Coventry.

OBJECTS AND RULES

OBJECTS AND RULES

(I.) OBJECTS.

The objects for which the Institution is established are :—

(*a*) To promote the science and practice and raise the status of engineering as applied to production; and to initiate and carry through any scheme or to organise any movement likely to be useful to the members of the Institution and to the community at large in relation thereto.

(*b*) To hold meetings of the Institution for reading and discussing communications bearing upon engineering as applied to the matters enumerated in paragraph (*a*), or the application thereof, or upon subjects relating thereto.

(*c*) To enable engineers to correspond, and to facilitate the interchange of ideas respecting improvements in the various branches of the practice of engineering as applied to production, and the publication and communication of information on such subjects to the members.

(*d*) To establish scholarships, organise lectures, hold examinations, to grant premiums and prizes for papers and essays, and by any other similar means to enlarge the knowledge and improve the practice of engineering as applied to production.

(*e*) To establish, undertake, superintend, administer, and contribute to any charitable or benevolent fund from which may be made donations or advances to persons at any time employed by the Institution, or who are or may have been engaged in engineering work and are not members of the Institution.

(*f*) To establish, subsidise, promote, co-operate with, receive into union, become a member of, act as or appoint trustees, agents, or

delegates for, control, manage, superintend, lend monetary assistance to, or otherwise assist any associations and institutions incorporated or not incorporated with objects altogether or in part similar to those of the Institution, and which may prohibit the payment of dividend or profit to its members at least to as great an extent as such payment is prohibited to the members of the Institution.

(*g*) To establish, form, and maintain a library and collection of models, designs, drawings, and other articles of interest in connection with the development and improvement of production.

(*h*) To encourage the settlement of disputes by arbitration, and to act as or nominate arbitrators and umpires on such terms and in such cases as may seem expedient.

(*i*) Generally to protect the interests of engineers, and especially engineers engaged in production work (including design and advice).

(*j*) To alter or enlarge the above objects or any of them as may from time to time be found necessary and expedient, having regard to the progress of the Institution.

(II.) RULES.

MEMBERSHIP.

1. The Institution shall consist of Honorary Members, Ordinary Members, Associate Members, Graduates, Associates, Affiliates, and all of whom are included in the term "membership" and members.

2. No honorary member, associate member, graduate or associate, or affiliate, shall, by reason of being legally a member of the Institution, be entitled to any privileges other than those which by these rules attach to the specific class of members of the Institution to which he belongs, and wherever the term "member" is hereinafter used without qualification, it shall be taken to mean ordinary member, and exclude honorary members, associate members, graduates, associates, and affiliates.

3. The Institution may admit such other person as may be hereafter qualified and elected in that behalf as honorary members, ordinary members, associate members, graduates, associates, and affiliates, respectively, but such persons shall sign such form of application as may from time to time be authorised by the Council.

4. The rights and privileges of every honorary member, ordinary member, associate member, graduate, associate, and affiliate shall be personal to himself, and shall not be transferable or transmissable by his own act or by operation of law.

ABBREVIATED TITLES.

5. The abbreviated distinctive titles to indicate the connection with the institution of Honorary Members, Ordinary Members, Associate Members and Associates shall be as follows:—For an Honorary Member, Hon.M.I.P.E.; for an Ordinary Member, M.I.P.E.; for an Associate Member, A.M.I.P.E.; for an Associate, A.I.P.E.

Such abbreviations shall not be used by any member who has resigned or been removed from the Institution, nor may they at any time be used upon any shop front, facia, or sign. If used upon door or wall plates or similar places, the abbreviations shall not exceed 1½in. in height.

CERTIFICATES.

6. Subject to such regulations as the Council may from time to time prescribe, the Council may issue to any Ordinary Member or Associate Member a certificate showing the class to which he belongs. Every such certificate shall be according to the form which may from time to time be approved by the Council, and shall remain the property of, and shall on demand be returned to, the Institution.

QUALIFICATIONS FOR MEMBERSHIP.

Ordinary Members.

7. Candidates for membership as Ordinary Members must be persons not under twenty-five years of age, and must produce evidence to the satisfaction of the Council that they :—

(*a*) Have received a good general education and scientific or engineering training, and

(*b*) Have for a sufficient period held an important position of independent responsibility in the practice of engineering production.

(*c*) Or are, by their attainments, deemed by the Council to be eligible for membership.

Associate Members.

8. Candidates for admission as Associate Members must be persons not under twenty-three years of age, and must produce evidence to the satisfaction of the Council that they :—

(*a*) Have received a good general education, and

(*b*) Have been trained as engineers and have for not less than two years been employed in the practice and science of engineering as applied to production, and shall be actually engaged in the work of such engineering at the time of their application for election.

(*c*) Or are considered by the Council to be qualified for election.

They may be transferred at the discretion of the Council to the class of Members.

Graduates.

9. Graduates shall be persons, not under eighteen years of age, who can show evidence that they are receiving practical training in engineering production, or who otherwise satisfy the Council that there are special circumstances which, in the opinion of the Council, entitle them to admission.

Graduates may not continue as such if they cease to follow such professional calling in production engineering, not in any case beyond the age of twenty-five. They may, however, on reaching this age be transferred, at the discretion of the Council, to the class of Associates.

Associates.

10. Candidates for admission as Associates must be persons, not under twenty-five years of age, who, not having the necessary qualifications for Associate Membership or Ordinary Membership, are or have been connected with design, tool design, research experiment, or organisation for production, and by reasons of their attainments in science or directive ability in manufacture, or works control, have interests in common with production engineering, and are, therefore, deemed by the Council worthy of Associateship.

At the discretion of the Council, they may be transferred, should they become eligible, to the class of Associate Members or Members.

Affiliates.

11. An Affiliated Firm shall be a firm, company, or individual interested in engineering as applied to production, or otherwise interested in the objects of the Institution.

An Affiliated Firm shall be entitled to nominate one member of their staff as an Affiliate for each payment of five pounds per annum to the funds of the Institution, provided always that such Affiliate shall be approved by the Council of the Institution. An Affiliate shall be entitled to attend all meetings in London and the provinces, the Summer Visit, and all visits to works, to receive the " Proceedings " and all other publications, to use the library, and to all other privileges of membership except that of voting and the use after his name of the authorised abbreviations of the Institution as set out in Article 5.

An Affiliate shall not be required to pay an entrance fee.

Honorary Members.

12. The Council shall have the power to elect as Honorary Members persons who, by reason of their past services to produc-

tion engineering, or by other eminent qualifications, are, in the opinion of the Council, eligible for that position.

ELECTION OF MEMBERS.

13. Elections shall take place as often as may be desirable, and they shall be made by the Council.

14. An application for admission to the Institution shall be made according to rules laid down by the Council and on forms to be approved by the Council; such rules or forms to be varied at the discretion of the Council.

15. The Secretary shall forward to each Candidate whose application has been considered and approved by the Council a notification of his election on such form as may be approved by the Council, but the applicant's name shall not be added to the register of the Institution until the entrance fee and first annual subscription shall have been paid. Failure to comply with this article within three months will nullify the election of the candidate.

16. In the case of non-election, no mention thereof shall be made in the minutes, nor any notice given to the unsuccessful candidate.

TRANSFERS.

17. Any member lower than the class of Ordinary Member, or any Graduate, desirous of being transferred to a higher class, shall forward to the Secretary a recommendation according to the rules laid down by the Council. Such recommendation shall be laid before the Council, at their next meeting, for consideration, and, if approved, the Secretary shall forward to the applicant a notice of his transfer, on such form as may be approved by the Council. The transfer will be completed upon payment of any difference there may be in subscription.

18. In the case of non-transference, no mention thereof shall be made in the minutes, nor any notice given to the unsuccessful applicant.

RESIGNATION AND EXPULSION.

19. Any Ordinary Member, Associate Member, Graduate, Associate or Affiliate notifying the Secretary, in writing, that he is desirous of withdrawing from the Institution, shall, after the payment of all arrears, if any, then due by him, cease to be included in the membership of the Institution, and his name shall be removed forthwith by the Institution from its register.

20. If any Member, Associate Member, Graduate, Associate, or Affiliate, shall leave his subscription in arrear from one year, and shall fail to pay such arrears within three months, after a written application has been sent to him by the Secretary to his last known address, his name may be struck off the register by the Council at any time afterwards, and he shall thereupon cease to have any right as a Member, Associate Member, Graduate, Associate, or Affiliate, but he shall nevertheless continue liable to pay the arrears of subscription due at the time of his name being struck off; provided always that this article shall not be construed to compel the Council to remove any name if they shall be satisfied the same ought to be retained.

21. The Council may by a majority of the whole of the Councillors refuse to continue to receive subscriptions of any Member, Associate Member, Graduate, Associate, or Affiliate, and may remove his name from the register without assigning any reason for so doing, and he shall thereupon cease to be an Ordinary Member, Associate Member, Graduate, Associate, or Affiliate.

ENTRANCE FEES AND SUBSCRIPTIONS.

22. Each Ordinary Member shall pay an annual subscription of £2 10s.

23. Each Associate Member shall pay an annual subscription of £2.

24. Each Graduate shall pay an annual subscription of £1.

25. Each Associate shall pay an annual subscription of £2.

26. Each Affiliate shall pay an annual subscription of £5 per nomination. (See Article 11.)

27. All subscriptions shall be payable in advance, and shall become due on the 15th day of July, and the first subscription shall date from the 15th day of July in the year of election.

28. In the case of Ordinary Members, Associate Members, Graduates, Associates, and Affiliates, elected in the last three months of any year, the first subscription shall cover the year of election and the succeeding year.

29. Any Ordinary Member, Associate Member, or Associate, whose subscription is not then in arrears, may compound for the then current year and all future years by the payment of 25 guineas or such other amount as may be approved by the Council.

30. Every new Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, may be required to pay an entrance fee on admission to the Institution, the amount of which shall be determined by the Council from time to time; but no payment, other than the increased annual subscription, shall be due on transference from one class to another.

31. Everyone admitted to the Institution, whether as Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, shall be considered as belonging thereto, and as such liable to the payment of his annual subscriptions and other payments, until his name shall have been removed by the Institution from its register.

32. No Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, whose contribution is six months in arrear shall be entitled to attend or take part in the meetings of the Institution, nor to receive the Institution printed papers, nor shall any such Ordinary Member, Associate Member, or Associate be entitled to vote. Any Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, whose contribution is fifteen months in arrear, shall be deemed to have forfeited his claim to all privileges of the Institution, and his name may be removed from the register by order of the Council, but he shall nevertheless continue liable to pay the arrears of subscription due at the time of his name being so removed, provided always that this article shall not be construed to compel the Council to remove any name, if they be satisfied that the same should be retained.

33. The Council may at their discretion reduce or remit the annual subscription or the arrears of the annual subscription of any Ordinary Member, Associate Member, Graduate, Associate, or Affiliate.

COUNCIL. CONSTITUTION AND ELECTION OF.

34. The Council of the Institution shall be chosen from the Members only, and shall consist of one President, not more than six Vice-Presidents, twenty-one Ordinary Members of Council, not more than four Past-Presidents, and not more than three Past-Vice-Presidents, and the Chairman of every local Section of the Institution constituted in accordance with the Articles of Association who has become *ex-officio* a member of Council (plus such other members as the Local Section has become entitled under Article 66).

The Council of the Institution shall have power from time to time, if, in their opinion, it is desirable to do so, to co-opt as additional members of the Council not more than three persons, who shall be nominated by any other Society, Corporation, or Body which shall have kindred interests with or further or assist the objects of the Institution. Such additional members shall hold office for such period and on such terms as may be agreed upon by the Council and the nominating body.

35. The President, not less than half the Vice-Presidents, and seven Ordinary Members of Council, shall retire at each Annual General Meeting, but shall be eligible for re-election, but no President shall hold office longer than two years without a break.

36. The Vice-Presidents and Ordinary Members of Council to retire each year shall, unless the Council agree otherwise among themselves, be chosen from those who have been longest in office, and in cases of equal seniority shall be determined by ballot.

37. The Past-Presidents, the Past-Vice-Presidents to serve upon the Council shall be appointed annually by the Council. They shall retire at each Annual General Meeting, but shall be eligible for re-appointment.

38. All Vice-Presidents who have served as such for a total number of eight years shall at the next following Annual General

Meeting cease to be Vice-Presidents, and shall become Past-Vice-Presidents, and other Vice-Presidents who have so served for a total number of six years may be appointed by the Council to be Past-Vice-Presidents, and shall on being so appointed cease to be Vice-Presidents.

39. The Council may supply any casual vacancy in the Council (including any casual vacancy in the office of President) which shall occur between one Annual General Meeting and another; and the President, Vice-Presidents, or Members of Council so appointed by the Council shall retire at the succeeding Annual General Meeting. Vacancies not filled up at any such meeting shall be deemed to be casual vacancies within the meaning of this Article.

40. Candidates for election as Councillors shall be nominated in writing at or before the General Meeting preceding the Annual General Meeting, when the Council shall present a list of their retiring members who are eligible, and willing to be re-elected. Any Ordinary Member or Associate Member shall be entitled to nominate candidates. The names, business and private addresses, occupations, and honorary titles of the candidates, together with the other Institutions to which they belong, shall be printed on a ballot list which shall be forwarded to the Ordinary Members and Associate Members at least seven days previous to the ballot being taken. The names of those elected to fill the offices of President and Vice-President and the names of the Chairman and of the Members of the Committees of the local centres elected by those Committees to represent them on the Council shall not be subject to ballot; but the names, addresses, titles, etc., of those so elected, together with the names of the non-retiring Councillors, shall be sent to the members with the ballot list. An Ordinary Member or Associate Member voting *against* a candidate shall strike out the name in accordance with the instructions on the ballot paper, as may be determined by the Council from time to time. Only those votes shall be effective which are recorded on lists reaching the Secretary by the specified date.

41. Candidates for the offices of President and Vice-President shall be nominated in writing by a Member of Council before the Council Meeting prior to that at which the election of President and Vice-Presidents takes place. They shall be elected by the

Council at a meeting held prior to the date of the Annual General Meeting, and shall hold office for a period of one year from the first Ordinary General Meeting of the Session following their election.

42. The first Council of the Institution shall consist of such as shall consent to act; the President and Councillors shall, save for resignation, hold office until the Annual General Meeting held in 1922. The Council so constituted may co-opt additional Councillors, provided that the number of the Council does not exceed that prescribed. Vacancies occurring between the one Annual General Meeting and the next may be filled by the Council.

PROCEEDINGS, POWERS, AND DUTIES OF THE COUNCIL.

43. The Council shall direct and manage the property and affairs of the Institution, and may regulate their own procedure, except that not less than five Councillors shall form a quorum. The Council may exercise all such powers of the Institution as might be exercised in General Meeting and the time being in force required, or by the Articles required or expressly directed to be exercised, or expressly declared to be exercisable by the Institution in General Meeting or with all the members of the Institution shall be bound by the acts and decisions of the Council subject nevertheless to any regulations of these Rules and to such regulations as may be prescribed by the Institution in General Meeting shall invalidate any prior Act of the Council which would have been valid if such regulation had not been made. Provided that the Council may with, but not without, the authority of a resolution of the Ordinary Members, Associate Members, and Associates in General meeting, borrow moneys for the purposes of the Institution on the Security of the property of the Institution or other available security, or otherwise, at their discretion.

44. The Council shall have power to consider and decide all matters not provided for by the Rules.

45. The Council shall at all times cause to be kept, in appropriate books, proper and sufficient accounts of the capital, funds, receipts, and expenditure of the Institution. The financial year

of the Institution shall end on the 15th July in each year; and a statement of the funds of the Institution and of the receipts and expenditure during such financial year shall be made, under the direction of the Council, each year, and after having been verified and signed by the auditors and approved by the Council shall be laid before the Annual General Meeting of the year following.

46. The Council may appoint Committees chosen from their own body, and Committees for special purposes consisting of members of the Council and Ordinary Members, Associate Members, Associates, and Affiliates of the Institution, and others, with such powers as the Council may prescribe. In the absence of the President, the Council or Committee shall elect a Chairman from among those present.

47. The President shall, *ex-officio*, be a member of all Committees of Council.

48. The Council, when they may consider it expedient to propose the enactment of any new Article, or the alteration or repeal of any existing one, shall summon the necessary Special General Meeting of Ordinary Members and Associate Members to decide the same; and the Council are at all times bound to summon such a Special General Meeting on a requisition, in writing, of ten per cent. but not less than fifty Ordinary Members, Associate Members, or Associates, specifying the particular new Article, or the alteration of an existing one, which they recommend.

49. It shall be the duty of the Council to adopt all due means for the advancement of the Institution; to provide for properly conducting its business in all cases of emergency; and to arrange for the publication, in such a way as they may deem desirable, of the papers read at meetings of the Institution, and discussions thereon, and of such documents as may be calculated to advance Production Engineering knowledge.

50. No act done by the Council, whether *ultra vires* of the Council or not, which shall have received the express or implied sanction of the Ordinary Members and Associate Members and Associates in General Meeting, shall be afterwards impeached by any person included in the membership of the Institution on

any ground whatever, but shall be deemed to be an act of the Institution, provided that, though *ultra vires* of the Council, it be within the powers of the Institution.

APPOINTMENT AND DUTIES OF OFFICERS.

51. The Treasurer of the Institution shall be appointed as and when a vacancy occurs by the Council, shall be removable by the Council upon one month's notice from any day, but in the case of serious negligence may be dismissed without notice. The Treasurer shall give one month's notice in the event of his wishing to resign.

52. The Treasurer shall hold and be responsible for the uninvested funds of the Institution; shall keep all the accounts necessary and proper for the purposes of the Institution; shall from time to time submit financial statements at the request of the Council; and shall pay all moneys into Bank, approved by the Council, upon receipt.

SECRETARY.

53. The Secretary of the Institution shall be appointed by the Council.

54. It shall be the duty of the Secretary, in person or by deputy, under the direction of the Council, to conduct the correspondence of the Institution; attend all meetings of the Institution and of the Council; take minutes of the proceedings of such meetings; to superintend the publication of such papers as the Council may direct; to have charge of the Library; and to conduct the collection of all subscriptions. He shall also engage and be responsible for all persons employed under him. He shall conduct the ordinary business of the Institution in accordance with these Rules and the direction of the President and Council.

AUDITORS.

55. The Auditors shall be elected annually by the Annual General Meeting, and shall be eligible for re-election on the expiration of their year of office.

56. It shall be left to the Council, as seems expedient to them from time to time, whether all or any of the Officers of the Institu-

tion be engaged for full or part time employment, and to fix their rate of remuneration, if any.

GENERAL MEETINGS.

57. The General Meetings shall consist of the Ordinary Meetings, the Annual General Meeting, and of Special Meetings, as hereinafter defined.

58. The Annual General Meeting shall take place in London in one of the first four months of every year. The Ordinary Meetings shall take place at such times and places as the Council shall determine.

59. A Special Meeting may be convened at any time by the Council, and shall be convened by them whenever a requisition, signed by 10 per cent., but not less than fifty Ordinary Members or Associate Members of the Institution, specifying the object of the Meeting, is left with the Secretary. If for fourteen days after the delivery of such requisition a Meeting be not convened in accordance therewith, the requisitionists, or 10 per cent. of the Ordinary Members or Associate Members of the Institution, and not less than fifty, may convene a Special Meeting in accordance with the requisition. All Special Meetings shall be held in London.

60. The quorum of the Annual General Meeting or of a Special Meeting shall be five. In the event of the quorum not being formed within half an hour of the time announced for the commencement of the Meeting, the Council shall be empowered to deal with the business of the Meeting.

61. Seven clear days' notice of every Meeting, specifying generally the nature of any special business to be transacted at any Meeting, shall be given to every person on the Register of the Institution, except as provided by Rule 77, in regard to Special Meetings, and Rule 79 in regard to General Meetings, and no other special business shall be transacted at such Meeting; but the non-receipt of such notice shall not invalidate the proceedings of such Meeting. No notice of the business to be transacted (other than such ballot lists as may be requisite in case of elections) shall be required in the absence of special business.

62. Special business shall include all business for transaction at a Special Meeting, and all business for transaction at every other Meeting, with the exception of the reading and confirmation of the Minutes of the previous Meeting, the election of Members, Associate Members, Graduates, Associates, and Affiliates, and the reading and discussion of communications and papers.

63. No person entered on the Register other than Ordinary Members, Associate Members, and Associates, shall have the right to vote at any Meeting of the Institution. Each Ordinary Member, Associate Member, and Associate shall have one vote. Honorary Members and Graduates and Affiliates shall not have votes at Meetings of the Institution.

LOCAL SECTIONS.

64. Local Sections of the Institution may be formed by the Council, consisting of Members, Associate Members, Graduates, Associates, and Affiliates of the Institution, in such local centres as afford evidence satisfactory to the Council :—

(*a*) Of a demand for the formation of a Local Section on the part of Members and Associate Members resident in the locality, and

(*b*) That a Local Section, if formed, will be so adequately supported and of such use to the Members, Associate Members, Graduates and Associates, and Affiliates in the locality that the Council will be justified in appropriating funds of the Institution towards its support.

The Council shall have power to dissolve such Section at any time after it has been formed.

65. The proposal for the formation of a Local Section shall be by petition of the Members and Associate Members resident in the locality. Such petition, together with the evidence as to the probable support and usefulness of the proposed Section, shall be brought before and considered by the Council, and if they decide that the Section shall be formed, a first Meeting of the Members, Graduates, Associates, and Affiliates resident in the locality shall be convened by written notice specifying generally the nature of the business to be transacted.

This Meeting shall be under the Chairmanship of a Member of the Council.

66. A Chairman of the Section (chosen from the Members only) and a Committee (chosen from the Members and Associate Members) for the management of the local affairs of the Section, subject to the approval of the Council, shall be appointed by resolution of the Members, Associate Members, and Associates resident in the locality at the first Meeting of the Section. To ensure proportional representation on the Council, the Chairman shall become *ex-officio* a member of Council, and where the Local Section is of such importance numerically the Section shall become entitled to elect such other members of their Committee as shall ensure the Section proportional representation on the Council. The Chairman and at least one-third of the Committee, including the additional representative to the Council, if any, shall retire at each Annual Meeting of the Section. Such retirement shall cancel their representation on the Council, but all members shall be eligible for re-election. Casual vacancies in the office of Chairman or in the Committee may be filled by the Committee, but those so appointed by them shall retire at the succeeding Annual Meeting of the Section. The election of a Chairman and members of the Committee (qualified as above) to supply the place of those retiring shall be conducted in manner prescribed by the Rules from time to time in force, as provided by Rule 67.

67. Each Local Section shall be constituted and its affairs shall be carried on in accordance with rules and regulations laid down from time to time by the Council.

68. The appropriation and contribution of funds of the Institution towards the expenses of Local Sections, or to enable such Local Sections to co-operate with Sections of other Institutions and Technical and Scientific Societies in the same locality for the purpose of forming Local Associations for the acquisition of Local Technical Libraries and Meeting Rooms and the provision of staff and equipment thereat for the common use of such Local Sections and Societies, consistently with the objects of the Institution, shall be in the sole discretion of the Council, and the Institution shall not be responsible for any liability incurred by or on behalf of any Local Section of the Institution or by or

on behalf of any such Local Association beyond any amount previously appropriated or contributed for any such specified purpose by the Council.

69. The Council may, subject to ratification at a General Special Meeting convened for the purpose, arrange for the union, alliance, or incorporation with the Institution of any Society with kindred objects; and may also, if they think fit, remit or reduce the entrance fees of the Members of such Society at the time of union, alliance, or incorporation.

PROPERTY AND FUNDS.

70. The property and funds of the Institution, and generally all its personal estate and all its real estate (if any) may be sold or disposed of by or according to the order and discretion of the Council, but only if and provided that it be sanctioned by a Special General Meeting of Ordinary Members, Associate Members, and Associates.

71. Any donation may be accepted by the Council and Treasurer in aid of the funds of the Institution.

72. All the moneys of the Institution in excess of such current balance in the hands of the Treasurer as the Council shall from time to time require the Treasurer to keep in hand to meet the current expenses of the Institution, shall be invested in any mode in which Trustees are or shall be by law, in absence of special direction, authorised to invest trust moneys under their control.

73. Every paper presented to the Institution, and accepted for reading or for publication in the "Proceedings," and the copyright thereof, shall be the property of the Institution, unless there shall have been some previous arrangement to the contrary. But the Council, in such cases as they may think fit, shall have power to release or surrender their rights in respect of any such paper or the copyright thereof.

74. Each Councillor shall be accountable in respect of his own acts only, and shall not be accountable for any acts done or authorised to which he shall not have expressly assented. No Councillor shall incur any personal liability in respect of any loss or damage incurred through any act, matter, or thing done,

authorised, or suffered by him, being done in good faith for the benefit of the Institution, if believed by him to be within although in excess of his legal power.

NOTICES.

75. A notice may be served by the Council or Secretary of the Institution upon any Honorary Member, Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, either personally or by sending it through the post in a prepaid letter addressed to such Honorary Member, Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, at his address, as registered in the books of the Institution.

76. Any notice, if served by post, shall be deemed to have been served at the time when the letter containing the same would be delivered in the ordinary course of the post; and in proving such service it shall be sufficient to prove that the letter containing the notice was properly addressed and put into the Post Office.

77. No Honorary Member, Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, not having a registered address within the United Kingdom, shall be entitled to any notice; and all proceedings may be had and taken without notice to such Honorary Member, Ordinary Member, Associate Member, Graduate, Associate, or Affiliate, in the same manner as if he had had due notice.

78. The Institution may appoint a periodical as the Official Organ of the Institution, for the publication of general notices and other information at the discretion of the Council.

79. After seven clear days from the date of publication any notice published in the Official Organ of the Institution shall be deemed to have been served on all Members.

80. These Rules may be altered by resolution of General Meeting at any time provided that in the notice calling such meeting it is stated that the alteration of Rules forms part of the business to be transacted.

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